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PHOTO-ELASTICITY.*

BY

PROFESSOR E. G. COKER, D.Sc., F.R.S.

University College, London.

IT MAY possibly be of interest to remark on so auspicious an occasion as the celebration of the centenary of The Franklin Institute that the subject of photo-elasticity, on which I propose to address you, is a branch of science which was founded just over a century ago by a discovery of Sir David Brewster that when transparent bodies are stressed they exhibit temporary doubly refractive properties.

Its origin has a degree of antiquity, therefore, which pertains to very few of the subjects to which your attention is directed here, since they are almost without exception either comparatively new, like the phenomena of X-rays or radio-activity, or else so very different from older speculations, such as, for example, the ultimate constitution of matter, that there is almost a complete break between ancient and modern science.

We have not, therefore, to deal either with a new subject, or yet with one which has changed its character in a revolutionary epoch.

The development of photo-elastic science has, however, some characteristics of its own which are of interest. Brewster was

* Address delivered Wednesday, September 17, 1924, on the occasion of the celebration of the centenary of The Franklin Institute.

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himself impressed by the possibilities of its application to engineering science, and, in fact, suggested that it would be possible to utilize it to determine the stresses in an arched bridge by aid of a glass model. Apparently little or no advance in our knowledge of bridge stresses resulted from this suggestion, and it was only in 1913 that a really important case of this kind was dealt with, when Mesnager [1] constructed a glass model of the reinforced concrete bridge in order to check the calculations for this important structure, a task which he accomplished with great success.

The history of photo-elastic science is in fact chiefly remarkable for its discontinuity, as it is only at intervals that one finds any attention paid to the subject by mathematicians and physicists, and hardly ever by engineers. The really notable contributions up to say 1855 are those by Neumann, Wertheim and Clerk-Maxwell, and there is little or no trace of any effort on the part of others to advance knowledge in this field, while it is only during the last twenty-five years or so that something approaching continuity is noticeable in the work of scientific men in this subject, one here and there scattered over the world, but still very small in number.

If it is possible to account for the past lack of interest in photo-elasticity, as this branch of science was named by Pearson, and especially by my own profession, it is, I think, partly due to the fact that the glasses, jellies and a few other transparent materials then available, were not at all suitable for research work on the distribution of stresses in bodies of complicated shapes. Glass has a comparatively feeble optical coefficient, although this is a minor matter in comparison with the difficulty of shaping it to any given form except the simplest of geometrical figures, and this latter defect is not compensated for by the perfection of its behavior as an elastic and also as a temporarily double refractive body under stress. Jellies and other long-known colloids have obvious deficiencies, and it is really to the chemists that we owe the advantages we now enjoy of a considerable range of transparent bodies suitable for engineering research on the stress distributions in structures and machines.

Another reason, although not so potent a one, for the neglect

[1] "Détermination complète sur un modèle réduit des tensions qui se produiront dans un ouvrage," M. Mesnager, *Annales des Ponts et Chaussees*, Part IV, 1913.

of photo-elastic science by engineers, is a certain amount of distrust in the applicability of the results of the optical measurements on transparent models to those of actual structures in steel and other engineering materials.

It will, therefore, be useful to examine this fundamental question at the commencement of this discourse so far as it relates to the stresses in any form of plate stressed in its plane, and as the applications of photo-elasticity are so varied, some cases of contact stresses are selected as typical of their use in the solution of engineering problems of stress distribution. From the mathematical standpoint all such problems, with certain definite exceptions to be mentioned later, resolve themselves into the solution of a single differential equation involving a function x in the form $\nabla^4 x = 0$, in which no elastic constants are found and which cannot therefore occur in the function x itself, and as this latter gives immediately the stress system at any point, it is evident that the elastic constants can have no influence upon the stress distribution itself, provided the limits of elasticity are not overpassed.

It is perhaps, however, more convincing to show that this is so by actual experimental evidence and this is not difficult to provide, as will appear in some cases which it is proposed to mention, in which the results of calculation from the theory of elasticity are compared with stress measurement. Only relatively few practical problems are amenable to exact calculation, and as we are to deal with several cases of contact stress, it may be useful to commence with one of the simplest, such as is found, for example, when a shaft is forced into a solid fly-wheel. Such a case is readily examined qualitatively by forcing a disc of transparent material into a slightly conical hole, and as has been observed, there is no indication of stress anywhere, although the uniform radial pressures at the contour are very considerable.

This, however, agrees perfectly well with theoretical deductions, for this is a case where $\nabla^4 x = 0$ is independent of the angular direction of the coördinates with reference to the centre of the plate, and therefore the equation reduces to the simple form

$$\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\right)\right]^2 x = 0 \qquad (1)$$

giving as a solution

$$x = \alpha r^2 + \beta r^2 \log r + \gamma \log r + \delta \tag{2}$$

from which are derived the stresses

$$\left.\begin{aligned} \widehat{rr} &= \frac{1}{r}\frac{\partial x}{\partial r} = (2\alpha + \beta) + 2\beta \log r + \frac{\gamma}{r^2} \\ \widehat{\theta\theta} &= \frac{\partial^2 x}{\partial r^2} = (2\alpha + \beta) + 2\beta \log r - \frac{\gamma}{r^2} \\ \widehat{r\theta} &= 0 \end{aligned}\right\} \tag{3}$$

and since both $\widehat{rr}$ and $\widehat{\theta\theta}$ cannot be infinite in value, we have

$$\beta = \gamma = 0 \quad \text{or} \quad \widehat{rr} = \widehat{\theta\theta} = 2\alpha = p$$

where p is the applied normal stress and therefore

$$\widehat{rr} - \widehat{\theta\theta} = 0$$

as we find it, while $\widehat{rr} + \widehat{\theta\theta} = 2p$ of constant value as measurements of the lateral strain indicate.

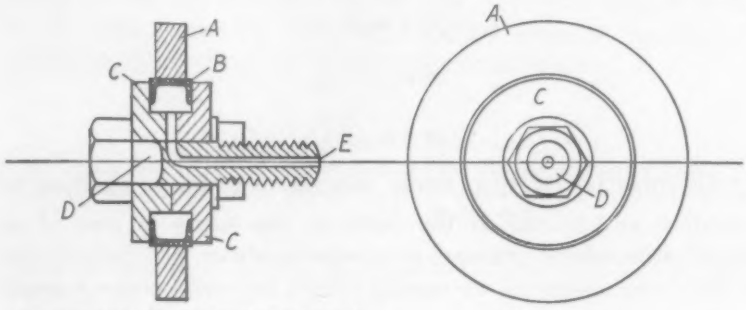
This equality of the radial and tangential components of the stress in the disc depends on the continuity of the material, and if the smallest hole or crack occurs in it the stress distribution changes in a very marked way, because all the radial stresses must be zero around the inner boundary and as a result when a cylindrical hole is bored anywhere color bands around it indicate how severe the stresses are. If, for example, a small hole is bored centrally, there will be observed concentric rings of color, which in fact mark the characteristic effects, observed in a thick cylinder when exposed to external pressure. Such experiments indicate in a general way the kind of distribution occurring, but they do not allow of accurate measurements or of comparisons with the theory of the stress distributions in thick cylinders to be carried out, and as various types of these are important in practice, it has been thought worth while to investigate this somewhat further by a very simple arrangement, in which it is possible to put a uniform and measurable pressure on either boundary.

For experimental work of this kind it is obviously important that all essential parts of the model under load shall be clearly visible in the field of view, and so arranged that the minute lateral changes which occur can be measured by an extensometer. These conditions can be obtained when applying uniform stress to the boundary of a cylindrical ring by a circular cup-leather of channel section, which is supported laterally by a casing supplied with fluid under pressure. The disc or ring is turned to fit the free

face of the cup-leather, and when fluid pressure is applied the object is uniformly stressed.

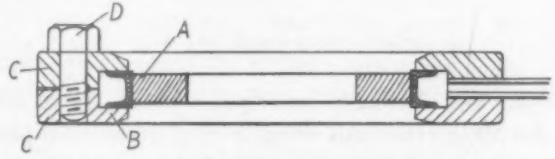
A device of this kind is shown in Fig. 1 for the application of pressure to the internal cylindrical surface of a ring or disc *A* supported by a flexible cup-leather *B*, fitting easily into a casing *C*, which latter is made in two halves and held together by a bolt *D*, while a pipe *E* serves to convey fluid under pressure to the

FIG. 1.



Cross-section of apparatus for applying a measurable fluid pressure to the inner surface of a ring.

Side view.



Cross-section of apparatus for applying a measurable fluid pressure to the outer cylindrical surface of a ring.

Apparatus for applying fluid pressure to models of thick cylinders.

inner face of the ring. The lower diagram shows a similar arrangement for applying stress to an external cylindrical boundary and is essentially of the same type. Some of the applied pressure is absorbed by the cup-leather, but as this latter can be made extremely thin the percentage loss is usually small and is not difficult to determine experimentally. Its amount may be diminished by making the ring rather less in thickness than the inner width of the cup-leather, and also by diminishing the depth of the side cheeks of this latter to the smallest possible value consistent with tightness under fluid pressure. Owing to the channel-shaped cross-section acting approximately as a beam with fixed ends, the distribution of load is probably not absolutely uniform across the

section of the model, and at these loaded boundaries there is a certain amount of discrepancy between experimental and calculated values, which is probably due to this cause, and the nature of which is immediately demonstrated by some experimental results obtained upon a circular ring with concentric boundaries. For such a case the stress distribution may be calculated from the general equations (3) by putting $\beta = 0$ to avoid infinite values of stress, whence we obtain

$$\widehat{rr} = 2\alpha + \frac{\gamma}{r^2}$$

$$\widehat{\theta\theta} = 2\alpha - \frac{\gamma}{r^2}$$

$$\widehat{r\theta} = 0.$$

At the inner boundary r_i under internal pressure p_i we have the condition $\widehat{rr} = p_i$ and at the outer r_o the stress is zero if we neglect atmospheric pressure in comparison with p_i. Substituting in the above equations we readily obtain the well-known formulæ

$$\widehat{rr} = p_i \frac{r_i^2}{r_o^2 - r_i^2}\left(\frac{r_o^2}{r^2} - 1\right)$$

$$\widehat{\theta\theta} = -p_i \frac{r_i^2}{r_o^2 - r_i^2}\left(\frac{r_o^2}{r^2} + 1\right)$$

These stresses are obviously principal stresses, as is also clearly shown by the black cross and circular ring shown in a plane polarized beam. The sum and difference of the principal stresses are,

$$\widehat{rr} + \widehat{\theta\theta} = -2p_i \frac{r_i^2}{r_o^2 - r_i^2}$$

of constant value, and

$$\widehat{rr} - \widehat{\theta\theta} = 2p_i \frac{r_o^2 r_i^2}{r_o^2 - r_i^2} \cdot \frac{1}{r^2}$$

These latter values afford a means of direct comparison with some observations made on a circular ring, .2523 inch thick, having an internal bore of 1.52 inches and an outer diameter of 4.00 inches when under an effective load of 469 pounds per square inch applied to the inner boundary.

For such a case the calculated sum of the principal stresses is 159 pounds per square inch throughout, but the observed values

(Table I) are slightly greater, except at and near the inner boundary where their variations are so great as to show that the assumed conditions of uniform pressure across the section are not realized. Apparently, however, this inequality does not produce so marked an effect on the optical value since they agree fairly well with the calculated stresses within a very short distance of the inner boundary, and support the view that although the actual distribution is imperfect, the integral value obtained by optical means across the thickness of the ring is a close approximation to the true value for accurately applied uniform loading, and substantially confirms the theoretical calculations.

TABLE I.

Dimensions of Ring—Thickness = .2523 Inch.
Effective Pressure at Interior Radius = 469 Pounds per Square Inch.

	Radius in inches.							
	.80	.825	.90	1.0	1.1	1.5	1.9	1.975
Observed $(\widehat{rr} + \widehat{\theta\theta})$ Calculated values = 159 lbs. per sq. in.	39	113	175	169	163	163	171	163
Observed $\widehat{rr} - \widehat{\theta\theta}$	1078	...	798	630	528	365	152	...
Calculated $\widehat{rr} - \widehat{\theta\theta}$	990	...	785	635	524	375	176	...

Numerous cases of this type have been examined, and in all cases the observed and calculated values have been found to be in good agreement.

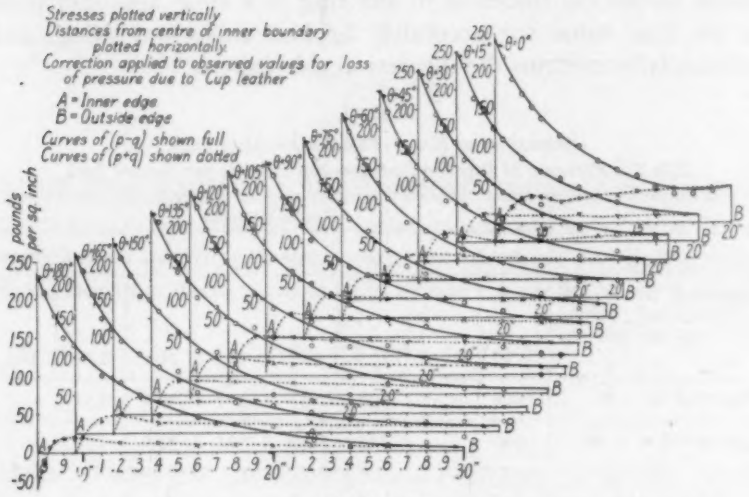
Although it is of comparatively rare occurrence, cylinders of circular cross-section may possibly have an eccentric bore, and it is therefore of interest to examine such cases, especially as the stresses become relatively intense at the thin side, as is shown when an eccentric ring is placed under internal pressure.

In order to illustrate this more fully, let us take an exaggerated example in which a cylinder of 5 inches external diameter with a bore of 1.518 inches diameter has two circular profiles centred at a distance $d = \frac{1}{2}$ inch apart (Fig. 2).

A very complete experimental exploration of this ring was made when under an internal pressure of 100 pounds per square inch, and it was found that the cup-leather absorbed 6.6 per cent.

of this pressure. The stress distribution was measured by the usual methods along lines radiating from the inner centre. The values of $(p \pm q)$ obtained by lateral measurements and the optical observations are shown in Table II, from which the accompanying semi-perspective diagram Fig. 2 is drawn to show the distribution at sections radiating from the centre of the bore at 15° apart. At the time these and other measurements were made,

FIG. 2.



Corrected sum and difference of principal stresses in eccentric ring under internal fluid pressure of 100 pounds per square inch. Stress distribution in a thick cylinder with an eccentric bore.

there was no available theory for this type of cylinder, but one of my colleagues, Dr. G. B. Jeffery, now professor of mathematics at University College, was as a matter of fact then engaged in a mathematical investigation of this problem by the method of bipolar coördinates, using the relation

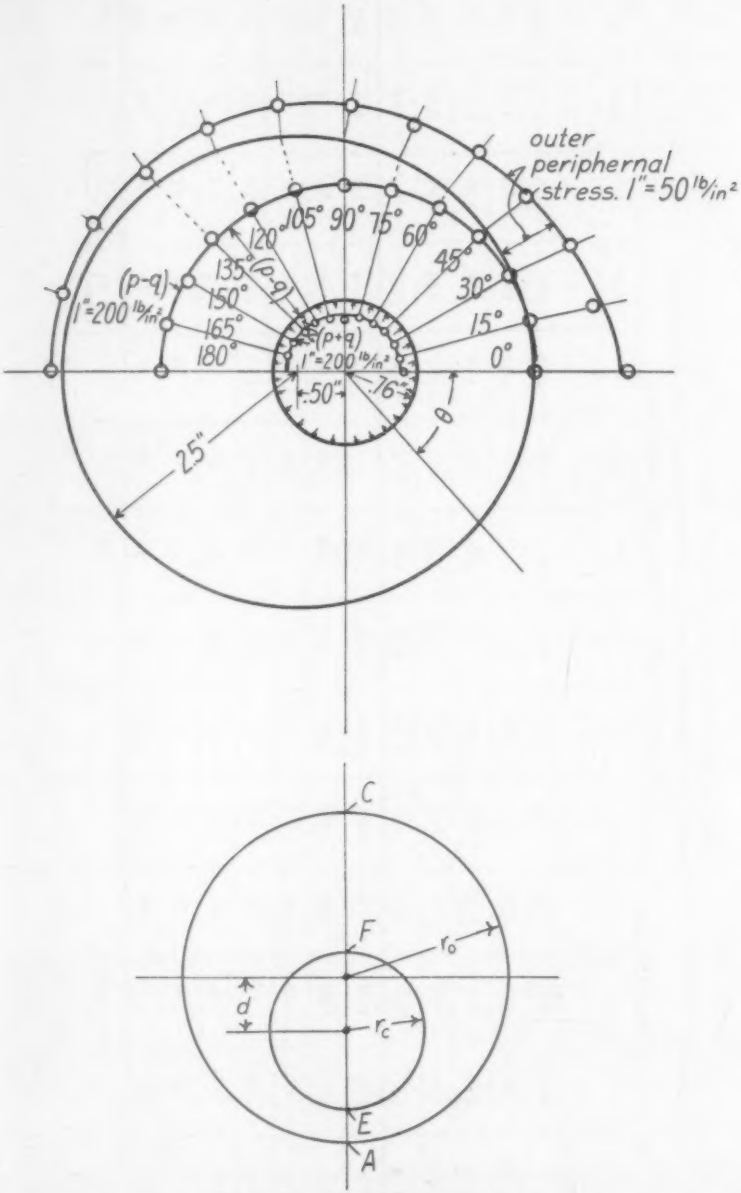
$$(r + ia)/(r - ia) = \varepsilon^{\alpha + i\beta}$$

for which

$$\alpha = \log \frac{r_i}{r_o}, \beta = (\theta_1 - \theta_2)$$

and he obtained an expression for the tangential stress $\widehat{\beta\beta}$ in the form

FIG. 2.



Peripheral stresses in eccentric ring No. II.
Stress distribution in a thick cylinder with an eccentric bore.

TABLE II.

Ring No. II.

Stresses in Eccentric Ring ($r_1 = .76''$, $r_2 = 2.5''$, $d = 0.5''$).

Correction for Cup-leather, etc., = 6.6 per cent. $p_1 = 100$ lb./in.^{2}.

Values of $(p-q)$ in Pounds per Square Inch.

θ	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
$R =$ (in inches)													
.8″	218	232	232	223	222	213	214	218	223	227	205	213	208
.85	189	188	193	181	186	181	185	188	192	182	182	181	178
.9	170	173	174	168	172	162	164	162	165	161	156	150	150
.95	150	149	156	149	153	153	147	151	151	149	149	137	140
1.0	137	135	133	133	133	132	129	128	130	126	134	120	123
1.1	115	109	116	105	101	115	95	112	112	114	108	104	101
1.2	101	92	90	98	90	90	92	96	88	93	82	77	92
1.3	80	83	79	82	83	67	82	81	82	88	80	71	75
1.4	69	71	75	67	66	58	79	67	70	112	60	54	48
1.6	47	52	42	56	47	49	54	47	37	64	20	40	45
1.8	37	39	33	31	43	37	45	39	39	22	17	35	36
2.0			28	36	23	31	34	22	22	14	25	28	34
2.2						11	22	11	−22	14	−11	17	28
2.4							6	3	11	8	−11	−17	6
2.6									0	6	−11	11	22
2.8										0	−11	−6	11

TABLE II—*Continued.*
Values of $(p+q)$ in Pounds per Square Inch.

θ	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
$R=$ (in inches)													
.775	−10						−32.4						−39
.8	−2	7.5	0	−1.7	8.3	−2.5	0	−8.3	0	−9.2	−2.5	−5.0	−16.6
.825													6.9
.85	20												14.1
.90	33.3	35.8	37.4	31.6	30.0	30.0	31.6	26.1	25.0	18.3	21.6	15.8	17.5
.95	33.3												19.1
1.0	33.3	33.3	33.3	34.1	30.8	25.0	26.6	27.4	23.3	19.1	15.0	23.3	17.5
1.1	26.6						25.8	25.8					
1.2	32.5	35.0	25.0	33.3	25.0	25.0	25.0	22.4	16.7	16.7	15.8	13.3	12.5
1.3	35.8		25.8				25.0	20.8					
1.4	35.8	35.8	25.8				25.0						11.7
1.5	40.8			29.1	25.8	25.8		22.4	13.3	15.0	16.7	12.5	
1.6	41.7	33.3					22.5						8.3
1.7	41.7		32.4					18.3					
1.8	42.5	34.9		25.0			20.8						9.2
1.9	45.8				25.0	24.1							
2.0	(49.1)	35.8	34.1		25.8		19.1	17.5	15.0	12.5	13.3	11.7	7.5
2.1				26.6									
2.2						19.1	17.5						8.3
2.3						18.3		16.6					
2.4							17.5		12.5				8.3
2.5								(16.6)		10.0	9.2	10.0	
2.6									10.0				6.7
2.7													
2.8										4.1	8.3		5.0
2.9												6.7	
3.0													(5.0)

$$\widehat{\beta\beta} = \frac{2p_i r_i^2 \left\{r_o^2\left(r_o^2 - 2d\cos\beta\right)^2 - \left(r_i^2 - d^2\right)^2\right\}}{\left(r_i^2 + r_o^2\right)\left\{r_o^2 - \left(r_i + d\right)^2\right\}\left\{r_o^2 - \left(r_i - d\right)^2\right\}}$$

from which it is possible to check the accuracy of the measurements in this and other cases.[2]

TABLE III.

Mean Thickness of Rings = .2523 Inch.
Press P_1 = 100 Pounds per Square Inch.

Number of Ring.	II.	IV.	VI.	IX.
Internal radius r_1 (inches)	.759	.759	.759	.751
External radius r_2 (inches)	2.500	1.748	1.244	.906
Eccentricity d (inches)	.50	.253	.249	.028
Experimental pressure. Percentage correction for cup-leather	6.6	6.6	13.6	18.8
Tangential stress in pounds per square inch at:				
Point *A*. Experimental	45	85.2	350	562
Calculated	44	83.0	314	560
Point *C*. Experimental	8.2	24.9	47.3	351
Calculated	8.0	28.0	48.0	336
Point *E*. Experimental	129	164	362	642
Calculated	135	172	360	663
Point *F*. Experimental	117	137	176	466
	123	140	180	464

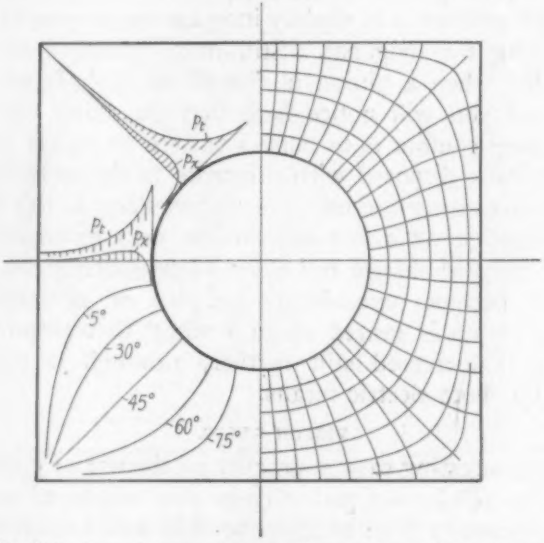
In four other cases of eccentric cylinders, having the dimensions shown in Table III, the stress distribution was also determined as accurately as possible and, as will be observed, the agreement is a remarkably close one. It affords a good illustration of some very careful experimental work of my then assistant, Dr. K. C. Chakko, in determining the stress distribution in a practical case, where the complete theoretical solution was then unknown and confirms this latter in a very satisfactory manner.

It is clear that it would be possible to determine the stress distribution in many other cases of this type, some of which are amenable to calculation and others are probably not very tractable in the mathematical sense. Taking, for example, that of a gun

[2] "Plane Stress and Plane Strain in Bipolar Coördinates," G. B. Jeffery, *Phil. Trans.*, Series A., Vol. 221, 1920.

built up by shrinking cylinders one upon the other, the stress and strain calculations of which are familiar to students of gun construction. Commencing with entirely unstressed rings, the first stage of shrinking on the first ring is illustrated by forcing this latter on to the innermost one in a press, the contours being suitably coned to permit this, and we then have both rings subjected to radial stress produced by definite strains, which can

FIG. 3.



Isoclinics, lines of stress and stress distributions in a thick cylinder.

be correlated with the stress distributions they produce. Forcing on a third ring we bring back the second to very nearly a state of ease, as sometimes occurs in practice, while the last stage representing the firing stresses is illustrated by forcing in a central plug, and you now see the final stress distribution as represented by sets of color bands all approximately concentric and capable of being interpreted by the eye and also readily converted into stress by simple optical measurements.

There are, however, many other cases where it would be more difficult to supply an effective theoretical analysis, such as, for example, the case of a cylinder formed by boring out a solid ingot of square cross-section and intended to sustain great inter-

nal pressure. An example of such a cylinder is now before you under internal stress, and you will notice at once that the effect of the outer square contour is to cause the color bands to bulge outwardly in the direction of the angular points, and a stress difference of higher intensity at the inner contour occurs at these sections as compared with those obtaining along the principal sections.

These stress distributions are shown in Fig. 3, together with the lines of principal stress, and they prove that the effect of the square outer contour is to slightly increase the stresses at the inner contour along the diagonal. Still more complicated examples are provided when a pinion is forced on a shaft as you now observe, and you will notice here that the effect of the teeth upon the inner contour is to cause a pattern to appear here which is symmetrically disposed with reference to the teeth and marks their effect in causing non-uniform contact stress at this boundary. The introduction of a key-way in the next example naturally produces a marked change and when a key is driven in, the stress distribution becomes exceedingly complex in its neighborhood, and if the pinion is geared up to a wheel to transmit load the complexity is increased still further, although it can still be measured by photo-electric means.

PISTON RINGS.

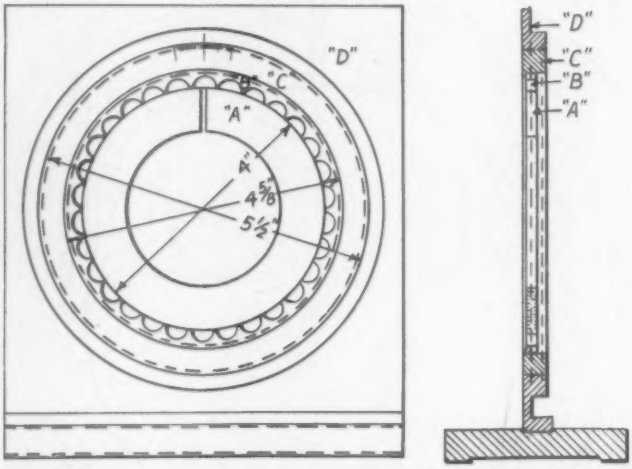
A very interesting case in practice of the use of contact stress arises in the well-known piston rings now employed universally. It is not necessary here to describe this well-known device, in which a thin ring, exerting an outward pressure of a few pounds per square inch only, is able to ensure a tight joint between the two sides of a piston even under great differences of pressure. These contact pressures are so small, however, that it makes a photo-elastic investigation of these rings somewhat difficult so far as this relates to the contact pressure itself, and in order to overcome the difficulty of measuring a very small pressure the experimental apparatus was designed to give much greater pressures than are usual, partly by employing rings of considerable breadth, and relatively large radius compared with the enclosing cylinders and also by localizing the areas of contact in such a way as to make them more easily measurable without departing to any great extent from the conditions met in practice.

From an experimental point of view, it appeared necessary to

widen the range of the stress conditions, and to vary them somewhat, in order to obtain the characteristic features which the problem presents.

The arrangement used is of a simple character and consists of a brass ring *C* (Fig. 4) capable of angular adjustment in a fixed casing and carrying an internal ring *B* of transparent nitrocellulose, which latter is cut at one or more points to prevent circumfer-

FIG. 4.



Apparatus for investigating the stress distribution in piston rings.

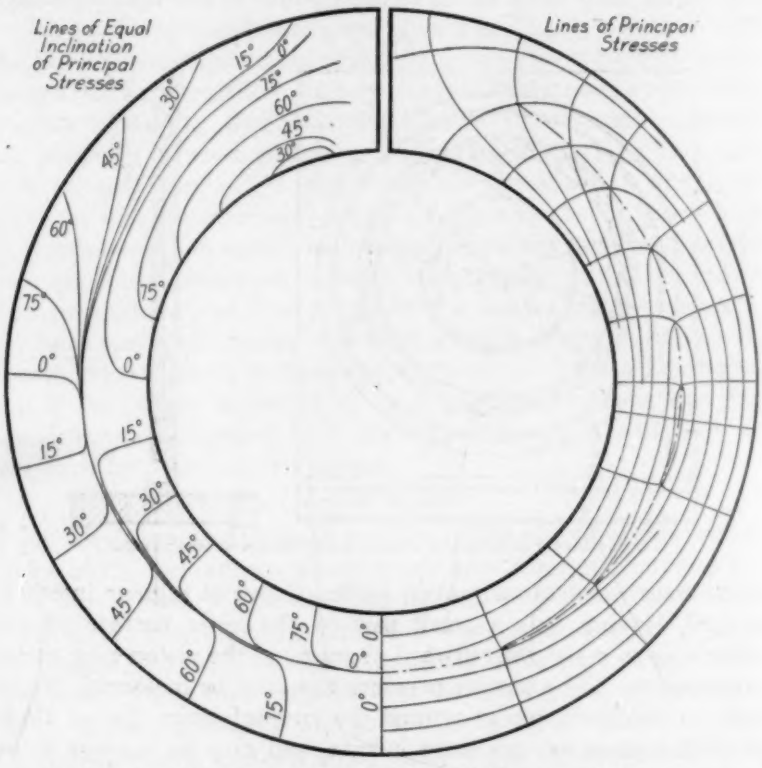
ential stress, and is, moreover, scalloped out at regular intervals of 12°, leaving only a small part of the inner surface of the latter ring to resist the outward pressure of the piston ring under examination. The contact pressure can only be measured, therefore, at thirty-six places around the circumference, but at these places the pressures are more intense, and give an average value of the pressure for the interval when due account is taken of the relation of the diminished area to the surface of a complete ring. When a ring is sprung into position in this apparatus, it is found that the pressure exerted on the points of the serrated ring is not quite normal, and, as a consequence, each tooth is subjected to some tangential stress, which is shown optically by some variation of color effect in the serrated ring. This tangential effect probably occurs in all piston rings in more or less degree.

In future work it is proposed to modify the points by making

the teeth more wedge-shaped in form, in order to measure the direction and intensity of the pressure with greater accuracy, and also with the object of obtaining better contact conditions than has been found possible so far.

The general character of the problem may be illustrated by the

FIG. 5.

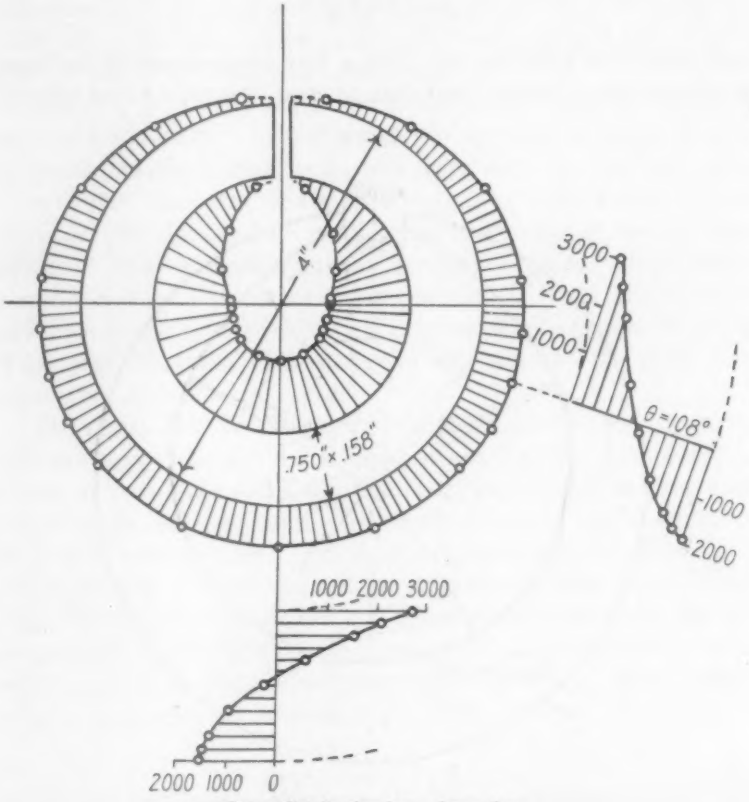


Lines of equal inclination of principal stresses and lines of principal stresses. Concentric ring .750" thick.

case of a piston ring initially of 4.120 inches external diameter, 0.750 inch wide and .158 inch thick, when sprung into a circle of 4 inches diameter. The isoclinic lines for this case were observed in my laboratory by Prof. T. Inokuty, of Tokio University, who very kindly undertook to make the observations for this and other rings, and for this case he found them to be of the form shown on the left-hand side of Fig. 5. The lines of principal

stress deduced from these latter are shown on the right hand of this figure, and they indicate some variations of contact pressure which are mainly due to the piston ring not being a very good fit in the outer ring. In this case contact pressures

FIG. 6.



Stress distribution in a piston ring.

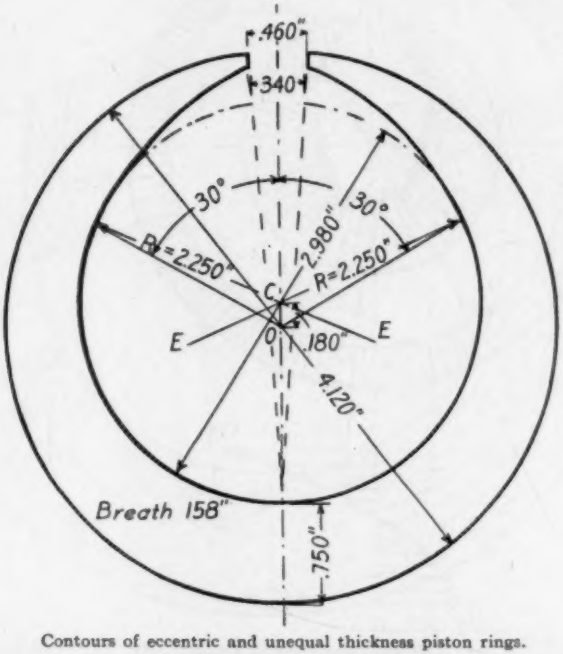
were observed which varied between 3 pounds and 4½ pounds in the lower quadrants, but in the upper quadrants there was little or no contact, except at the free ends, and in consequence of this the bending moment in the ring decreased somewhat from $\theta = 90°$ to $\theta = 180°$, as shown in the polar diagram (Fig. 6), which shows the stresses at the interior and exterior contours and at two cross-sections where $\theta = 108°$ and $\theta = 180°$. These latter

indicate that the stress distribution across the ring at any section is non-linear and of the type indicated by the Andrews-Pearson-Winkler formulæ. This latter deduction is of importance, since the usual theory of piston rings assumes that the stress distribution law is of the type

$$\frac{p}{y} = \frac{M}{I} = E\left(\frac{1}{R} - \frac{1}{R_o}\right)$$

and while this formula may give a fair approximation for many practical cases, it seems clear that, at least, it is only a first approxi-

FIG. 7.



Contours of eccentric and unequal thickness piston rings.

mation to the actual facts, and that it would be more precise to take, let us say, the Pearson-Winkler formulæ as more nearly representing the conditions.

On the usual assumptions [3] it is easy to show that if the breadth of the ring at $\theta = 180°$ is b_1, the breadth b at any other angular position is given by

[3] Unwin's "Machine Design," Part II, pp. 207–213.

$$\frac{b}{b_1} = \sqrt[3]{\sin^2\theta}.$$

and a ring corresponding at its central section to the one described above, but otherwise designed by this formula, is shown in Fig. 7. Before completing the ring, however, it was examined as a case of a simple eccentric ring having an outer diameter of 4.120 inches as before, and the inner diameter of 2.980 inches with an eccentricity of 0.180 inch, which latter curve corresponds very closely with the above formula when θ is large.

The ring was afterwards completed as the formula indicates and again examined. In both cases the rings were found to bear all round, but the contact pressures were not very uniform, and, in particular, the outer free ends of each ring show comparatively excessive pressures, which would tend to scoring of the cylinder surface. This is made clear by a study of color photographs in which this excessive contact pressure at the free ends is clearly visible; it is not so noticeable in the corresponding case of a ring of unequal thickness when designed according to the usual formula given above.

The stress distributions across the sections $\theta = 180°$ are naturally not very different for the two cases, but the measurements appear to show that the diminuations of breadth at the free ends have a slight but progressive tendency to throw more stress on the central cross-section. There is also a marked departure from a straight line law, but it must be remembered that there is also cross-stress on each section which has not been measured, but we are probably entitled to assume that it is of approximately parabolic form, with a slight compression value at the outer contour rising to a maximum at or near a radius r where

$$r^2 = \left(2r_i^2 r_o^2 \cdot \log \frac{r_o}{r_i}\right) / (r_o^2 - r_i^2)$$

as given by the theory of the curved beam under uniform bending moment, and then diminishing to zero at the inner contour. The effect of this upon the form of the experimental curves of distribution found here, which are practically curves of principal stress difference, is bound to be small, and although the correction tends to make the distribution approach linearity, it is not likely to correct this completely.

THE STRESSES IN DOVE-TAIL JOINTS.

One of the oldest contrivances for fastening two members together in a permanent manner is the joiner's device of a dove-tail joint, but it is only of late years that this form of fastening has been much used by engineers for connecting parts together. Such joints now occur in great variety in engineering practice, the blades of steam turbines are, for example, almost invariably keyed to discs or drums by dove-tailing them into suitable grooves to form a rigid connection, while in electrical machinery pole-pieces and armature conductors are often secured in a similar fashion.

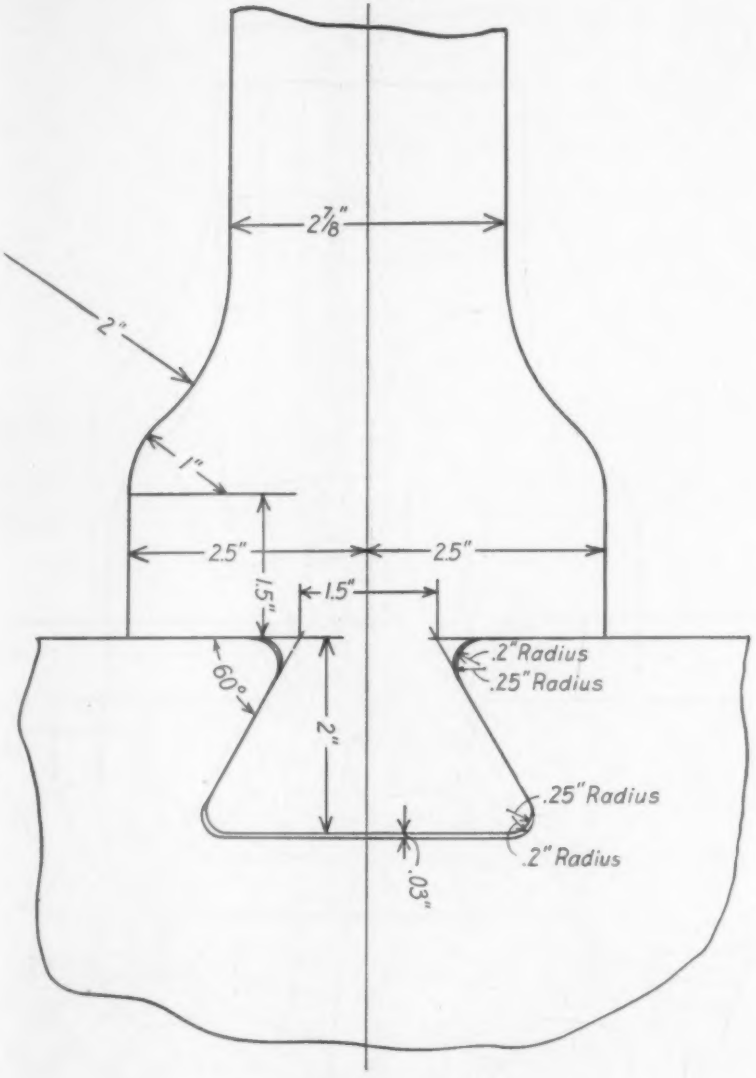
So long as these jointed members remained small, the loads which came upon them were not such as to cause any serious difficulty due to overstress at any point, and much more attention was therefore paid in design to secure ease of attachment and removal, but to-day the problem is not so simple for steam turbine and electrical generator units have now become so large that the stress effects in such joints have become of importance. It may therefore be of interest if the stress distributions in one or two cases are examined, and for this purpose I am privileged to make use of some data obtained for the Metropolitan Vickers Company, Limited, of Manchester.

In order to examine the stress distribution in a simple dove-tailed joint of the form shown by Fig. 8 a full-sized brass template was prepared and models one-quarter full size cut from transparent nitrocellulose sheets were made in a copying machine and loaded by tension applied axially in a field of polarized light.

Using plane polarized light it is comparatively easy to determine the directions of stress in such a member by observations of the changes of form of the isoclinic bands produced in the field of view when the crossed Nicols are rotated, and although the bands are numerous and somewhat complicated, as the left-hand side of Fig. 9 indicates, there is no difficulty in determining by geometrical construction the positions and forms of the lines of principal stress as shown in the same figure.

A combination of optical and mechanical measurements also allows of a complete survey of the stress distribution in the joint when reference is made to a standard tension member cut from

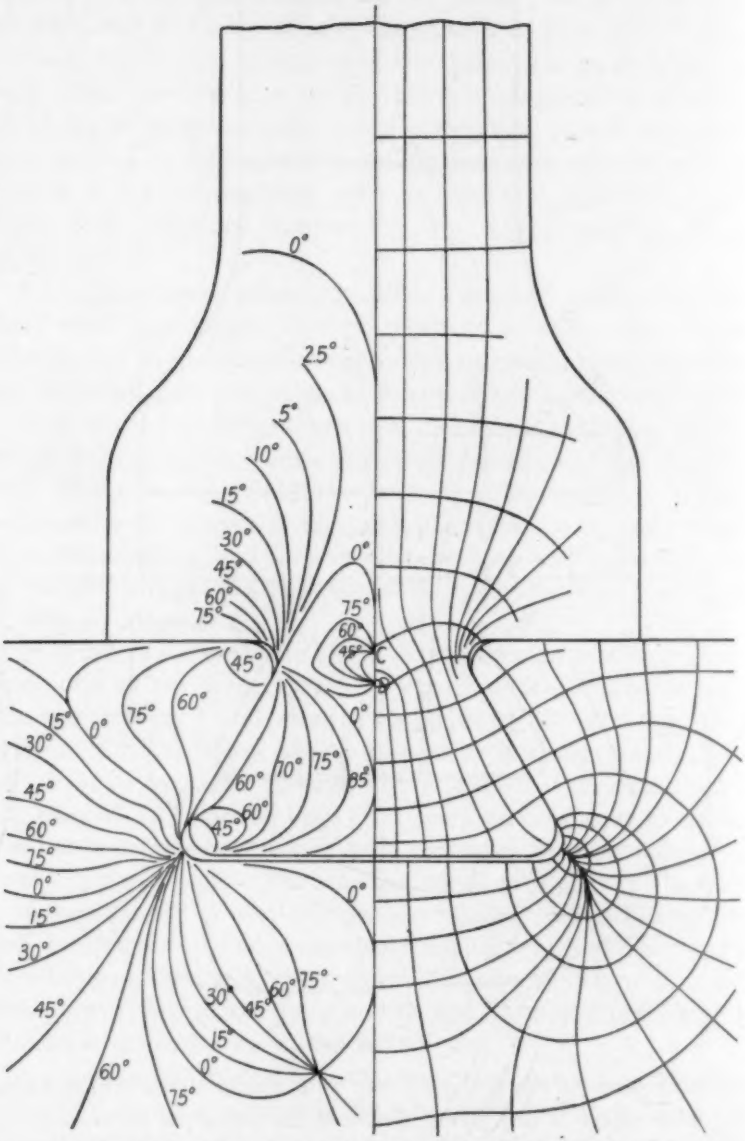
FIG. 8.



Dove-tail joint.

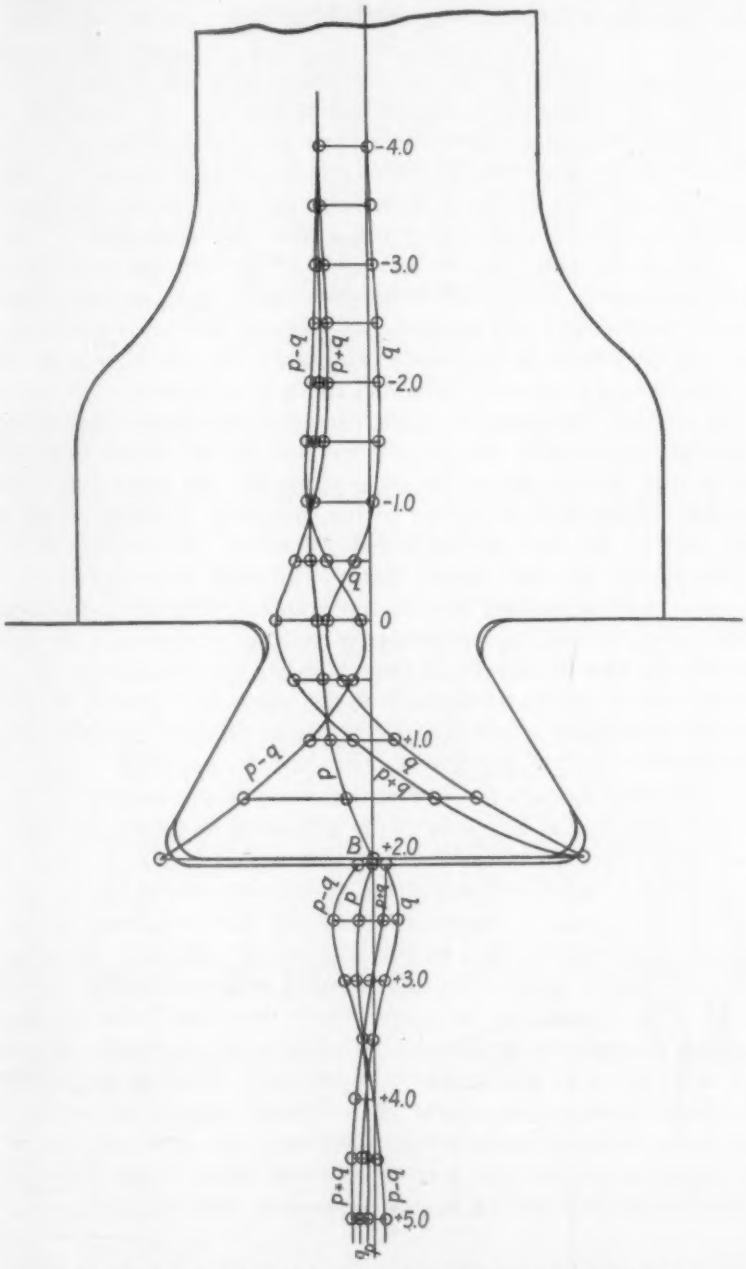
the same plate as the specimen, for if t_1 is the stress which annuls the color effect at any point A where the principal stresses are p_1 and q_1, then $t_1 = p_1 - q_1$, while if t_2 is the stress in the same calibra-

FIG. 9.



Isoclinics and lines of principal stress in the dove-tail joint of Fig. 8.

FIG. 10.



Stress distribution along the longitudinal section of the dove-tail of Fig. 8.

tion member which gives the same lateral change as at the point A, we have also $t_2 = p_1 + q_1$, and therefore

$$p_1 = \frac{1}{2}(t_2 + t_1) \qquad q_1 = \frac{1}{2}(t_2 - t_1)$$

subject to unimportant corrections which are not necessary to consider here, since these have been fully described.[4] All the measurements are obtained directly in terms of stress in the form $(p \pm q)$ and the actual observations are plotted on the figures together with the values of p and q obtained from them.

Along the axial line of this joint (Fig. 10) the variation of tensional stress p is found to be quite small; it is, in fact, nearly uniform until well into the dove-tail, where it decreases and falls to zero at the lower edge as clearly it must do. On the other hand, the cross-stress q is very variable and there is quite a large compression stress at the point B in the centre of the lower edge of the dove-tail with three changes of the sign of the stress along the axial line. At two places the cross-stress has the same magnitude as the longitudinal stress, but owing, however, to small errors on the part of the observer the p and q lines are not actually shown crossing one another on this figure, although they should cross, since it will be noticed that at the points C and D of the axial line (Fig. 9), all the neighboring isoclinics terminate at these points and therefore indicate that these are places where $p - q = 0$. These points are also indicated on the color photograph obtained of the joint under stress, where it will also be noted that the stress in the lower part of the dove-tail is also very apparent.

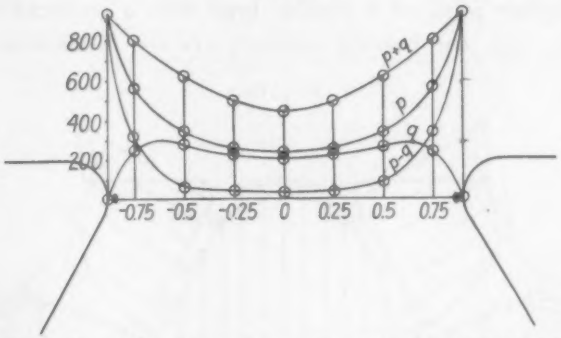
The chief feature of interest, however, is the marked concentration of stress at the ends of the minimum cross-section, which one naturally expects to be great, although it is not so apparent why there is so little visible stress effect in the central part. The reason for this latter becomes quite clear, however, when a complete exploration is made of this section, as, although the optical effect $(p - q)$ is small except at the ends, as shown by Fig. 11 and Table IV, the sum $(p + q)$ observed by the lateral measurements is high throughout, so that the half sum of the ordinates between the curves $(p + q)$ giving the cross-stress q is nearly as large as the tensional stress p, except near the ends, and as it is also a tension stress the color effects must be comparatively small, as they are proportional to $(p - q)$. The tensional stress p has, however,

[4] "Contact Pressures and Stresses," *Proc. Inst. Mech. Engrs.*, 1921.

very pronounced maxima at the ends of the section giving the high stress of 2.67 p_m, where p_m is the mean average stress across the section.

Precisely the same distribution would be obtained in a similar

FIG. 11.



Stress distribution at the minimum cross-section of the dove-tail joint of Fig. 8.

steel member, and if it were necessary this could be shown, so far as the values of $(p + q)$ are concerned, by observations with a lateral extensometer.

TABLE IV.

Stress Distribution at the Minimum Section of a Dove-tail Joint.

Load = 60 pounds, Thickness = 0.1 inch.

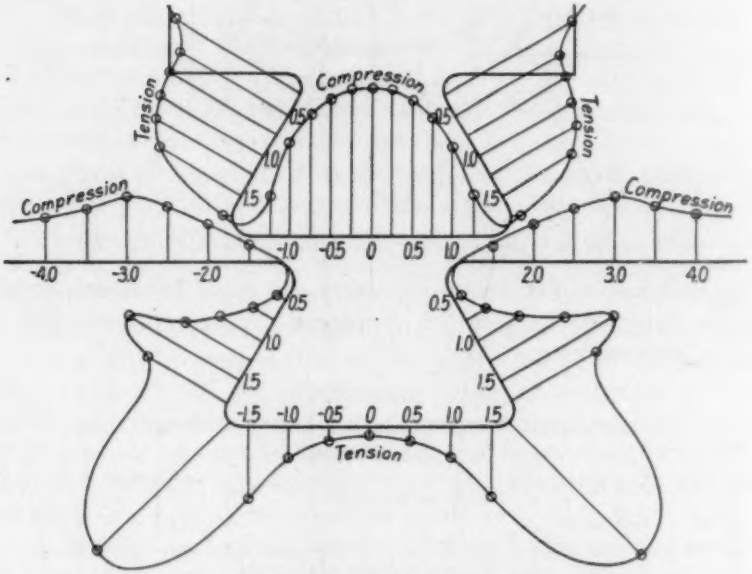
y Inches.	x Inches.	Pounds per Square Inch.				θ Degrees.	$\widehat{yy}$	Error.
		$p+q$	$p-q$	p	q			
0.20	−0.866	930	916	923	7	0	916	4.5%
	−0.75	790	316	553	237	5	549	
	−0.50	608	63	336	273	22	329	
	−0.25	487	32	260	228	50	241	
	0	430	30	230	200	90	200	
	0.25	487	32	260	228	50	241	
	0.50	608	79	334	265	22	325	
	0.75	790	332	561	229	5	557	
	0.866	930	930	930	0	0	930	

The effects of the load at the inner angular points of the dove-tail recess are also interesting and important, since they are large as the photograph shows. The stresses developed here are in fact greater than at any other places, and expressed in terms of p_m across the minimum cross-section they reach the high value of 3.29 p_m, or 12.3 per cent. in excess of those found at the ends

of the minimum cross-section. The contour stresses are shown to scale in Fig. 12 and in practice there would in general be an all-round increase in stress if the two parts of the joint were a force-fit instead of, as here, just fitting together without force being necessary to slip them into position.

In another joint of a similar type with a tee-headed projection (Fig. 13), the bearing surfaces are the horizontal faces *A*

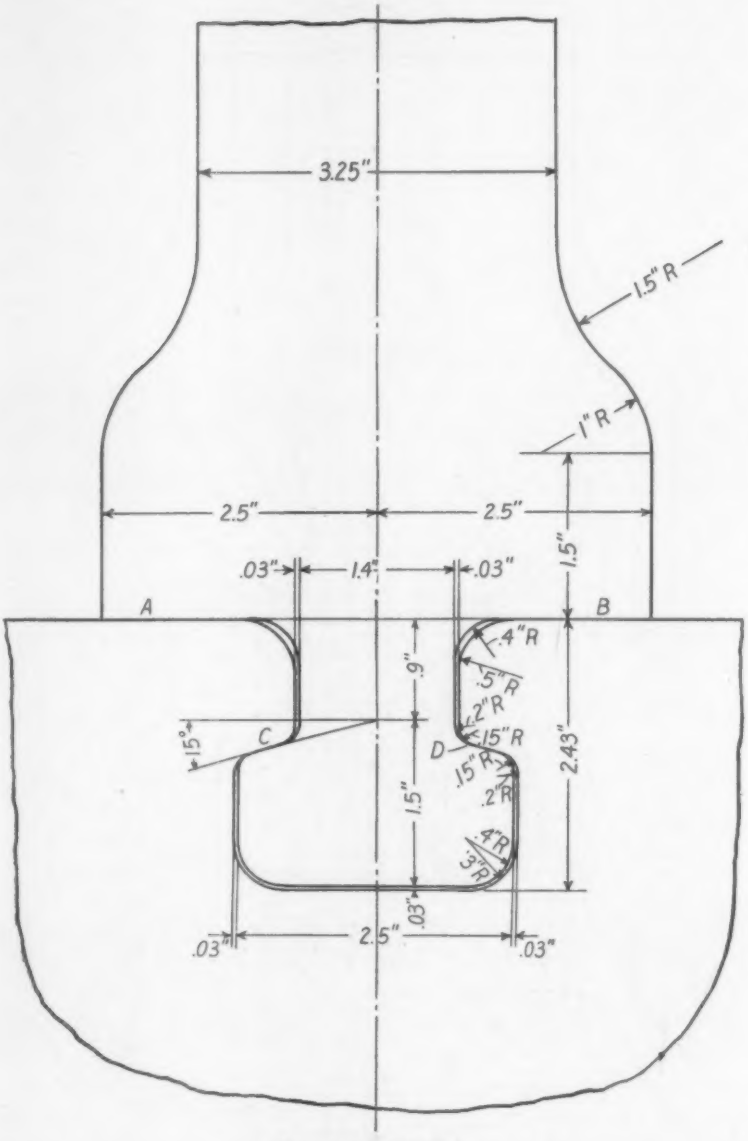
FIG. 12.



Load: 60 lbs. Thickness: 0.1". Scale of stress: 1" = 500 lbs./in.²
Contour stresses in the dove-tail joint of Fig. 8.

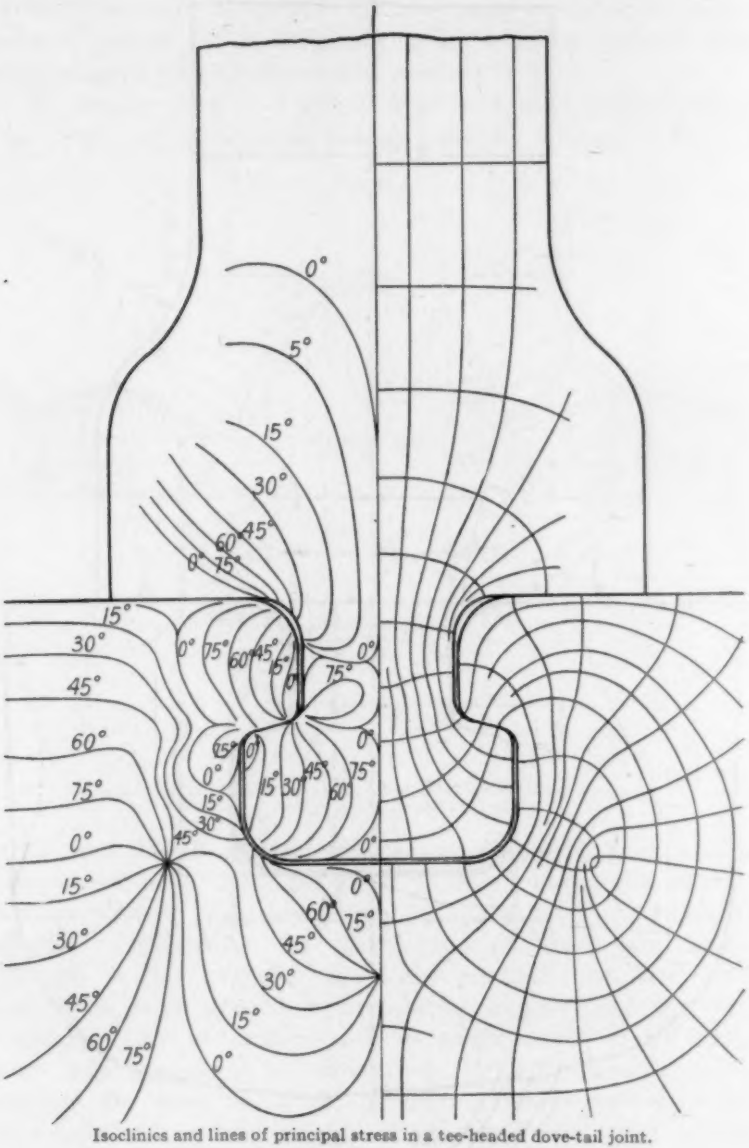
and *B*, and slightly inclined faces *C* and *D*, and in general these faces would be so arranged as to produce considerable bearing pressure between them before any load is applied. It would be possible to determine the distribution of stress so caused, although in this example, as in the previous one, the joints were made from brass templates fitting exactly, and no stress is produced by a force-fit such as might occur in an actual case. The procedure for examining the stress distribution is precisely the same as in the previous example, and although the isoclinic lines are perhaps more complicated than before, there is still little difficulty in finding the lines of principal

FIG. 13.



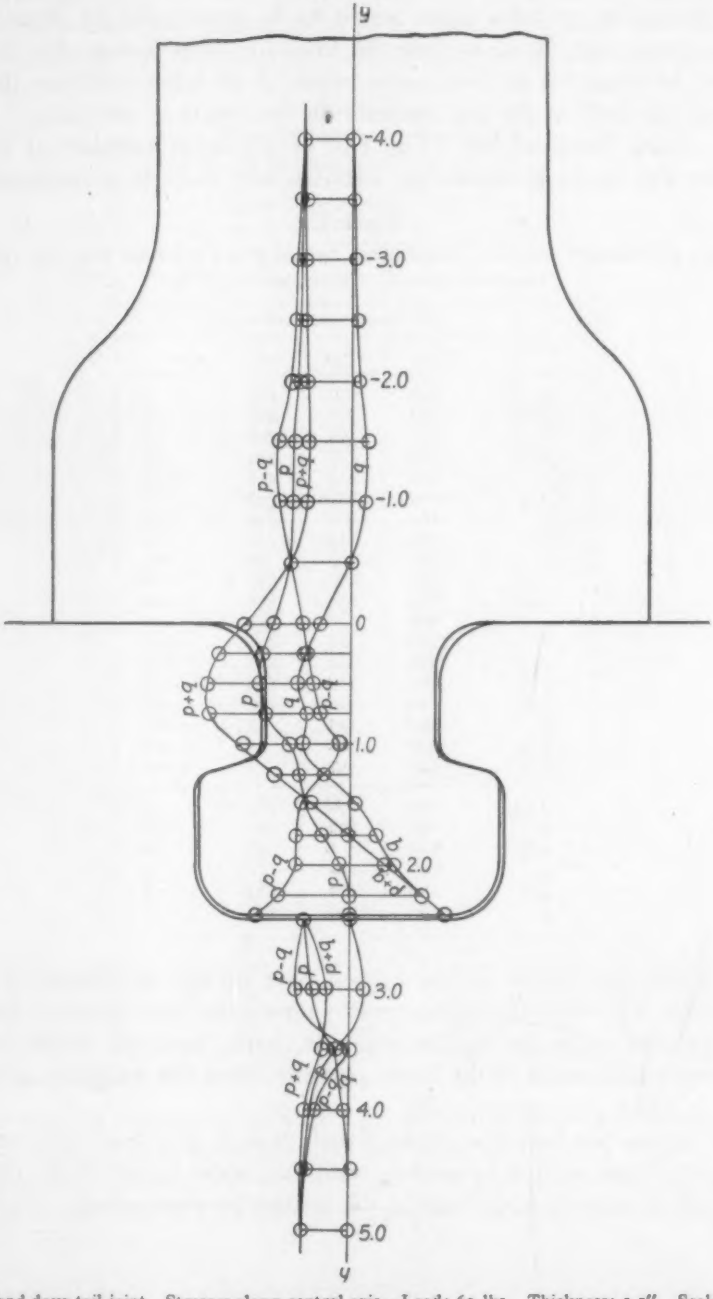
Second dove-tail joint.
Diagram of a tee-headed dove-tail joint.

FIG. 14.



Isoclinics and lines of principal stress in a tee-headed dove-tail joint.

FIG. 15.



Second dove-tail joint. Stresses along central axis. Load: 60 lbs. Thickness: 0.1". Scale of stress: 1' = 500 lbs./in.² Stress distribution along the axial line of a tee-headed dove-tail joint.

stress shown in Fig. 14, and it will be noted here that at the slightly sloping sides there seems to be practically no shear at the contacting faces, so that the lines of stress across this face may be regarded as continuous, while at all other contours they cease abruptly at the gap between the two parts of the joint.

Along the axial line (Fig. 15) of the upper member of this joint the stress is somewhat variable and rises to a maximum

TABLE V.

Stress Distribution along the Longitudinal Section of a Tee-headed Dove-tail Joint.
Load = 60 pounds, Thickness = 0.1 inch.

y Inches.	Pounds per Square Inch.			
	$p+q$	$p-q$	p	q
−4	200	190	195	5
−3½	195	205	200	−5
−3	190	222	206	−16
−2½	190	237	214	−24
−2	180	253	217	−37
−1½	180	316	248	−68
−1	180	300	240	−60
−½	250	253	252	−2
0	450	205	328	123
¼	550	190	370	180
½	600	158	379	221
¾	590	126	358	232
1	450	47	249	203
1¼	320	110	215	105
1½	160	205	183	−23
1¾	10	222	116	−106
2	−140	222	41	−181
2¼	−300	300	0	−300
2.4	−390	395	3	−393
2.43	190	190	190	0
3	90	222	156	−66
3½	110	0	55	55
4	180	142	161	19
4½	180	190	185	−5
5	190	190	190	0

at about the centre of the necked part of the tee-shaped head (Table V), while the cross-stress q shows the same general characteristics as in the earlier example, with, however, much less compression stress in the lower contour, since the wedging action is so much less pronounced.

Across the neck the stress distribution is found to vary very rapidly from section to section, with maximum values at the ends which increase in magnitude as the tee-head is approached. At the

section $y = \frac{1}{2}$ inch, for example (Table VI), the maximum stress is 600 pounds per square inch, or 1.4 p_m, where p_m is the mean stress across the section, while at $y = 1$ inch the maximum stress is

TABLE VI.

Stress Distribution in Tee-head.

Load = 60 pounds, Thickness = 0.1 inch.

y Inches.	x Inches.	θ Degrees.	Pounds per Square Inch. $p+q$	$p-q$	p	q	$\hat{yy}$	Error.
	Stress along Section ($y = \frac{1}{2}''$).							
½	−0.7	0	600	600	600	0	600	5%
	−½	3	600	474	537	63	536	
	−¼	2	600	237	419	182	418	
	0	0	600	158	379	221	379	
	¼	−2	600	237	419	182	418	
	½	−3	600	474	537	63	536	
	0.7	0	600	585	593	8	593	
	Stress along Section ($y = 1''$).							
1	−0.72	18	900	900	900	0	814	−5%
	−½	18	650	364	507	143	471	
	−¼	16	500	158	329	171	319	
	0	0	450	47	249	202	249	
	¼	−16	500	158	329	171	319	
	½	−18	630	364	497	133	461	
	0.72	−18	880	885	883	−3	798	

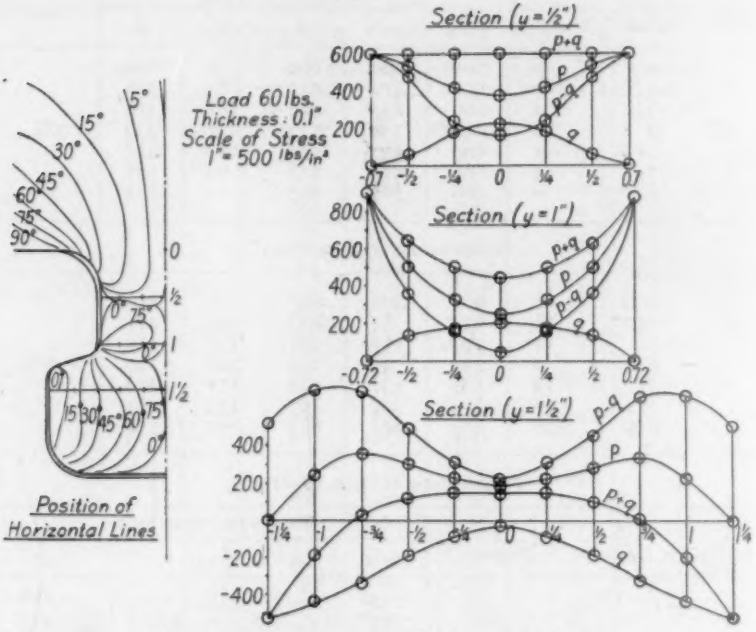
Stress along Section ($y = 1\frac{1}{2}''$).

y Inches.	x Inches.	θ Degrees.	Pounds per Square Inch. $p+q$	$p-q$	p	q
1½	−1¼	0	−530	522	−4	−526
	−1	22	−190	695	253	−443
	−¾	45	20	695	358	−338
	−½	62	120	490	305	−185
	−¼	77	150	316	233	−83
	0	90	150	222	186	−36
	¼	−77	150	316	233	−83
	½	−62	100	458	279	−179
	¾	−45	10	664	337	−327
	1	−22	−200	664	232	−432
	1¼	0	−530	506	−12	−518

900 pounds per square inch, or 2.08 p_m, and both are accompanied by considerable cross-stress q, as indicated in Fig. 16. Below the contacting surfaces the stress at the contour is reversed and is now compressive, thus at $y = 1.5$ inches its value is about 520

pounds per square inch and very nearly zero at the centre, accompanied by considerable cross-stress as the p curves show. The order of accuracy in these measurements is between ± 4 per cent., as shown when the integrated normal stresses in the two upper sections are compared with the total pull. The maximum stress was found at the lower ends of the contact areas and was slightly over 2000 pounds per square inch. Except for these areas the

FIG. 16.



Stress distributions in the tee-head of a dove-tail joint.

contour stresses are much less than those of the earlier case, when the mean average stress across the neck of the dove-tail is taken as the basis of comparison.

RADIAL DOVE-TAIL JOINTS.

The two examples already described are simple cases such as might possibly occur in the blading of a steam turbine disc, although no doubt the loading actually met with is more complex, but it would not be difficult, for example, to find experimentally the effects of definite combinations of simple tension and bending

applied to turbine blading, and in fact the field of experiment here is capable of great extension.

In another direction, particularly in some cases of large units, it is often necessary to secure heavy masses to a rotor by dove-tail joints spaced at intervals round the periphery, and if the speed is great the centrifugal effects are large and it becomes of importance to know the exact effects on such a rotor produced by the centrifugal pull of heavy rotating masses. It is usually quite impossible to calculate with any accuracy the stress distribution in such a complicated case, or even in the two earlier cases, but there is no real difficulty in determining this experimentally, and some preliminary measurements of the case now shown of eight radial dove-tail slots in a disc with a central hole indicate that stress-distribution problems of this type can be solved with comparative ease, and having regard to the variety of cases which occur in practice such experimental solutions may possibly be useful in the design of power units of an unprecedented scale.

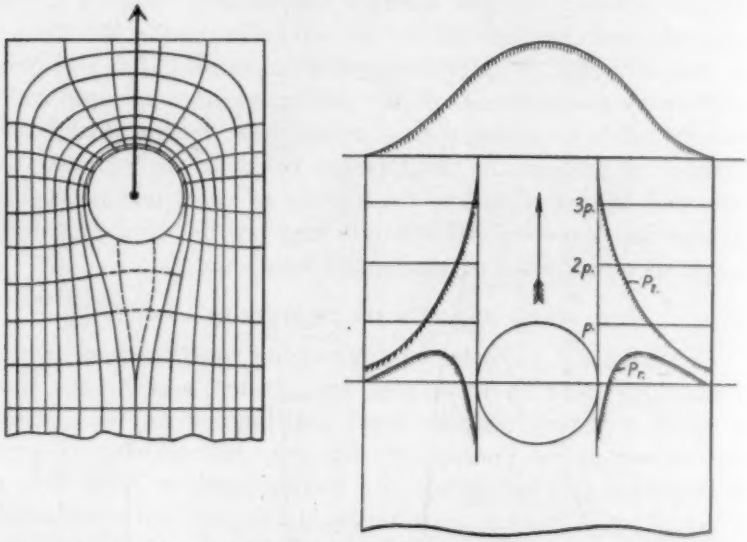
THE STRESS DUE TO A PIN OR RIVET IN A PLATE.

A variety of problems in engineering practice occur due to connections made by rivets, pins, keys, cotters and the like, most of which give very complex stress distributions, as, for instance, that shown in the photograph that may be obtained of a pin bearing against a hole made in a tension member. The lines of principal stress and the distribution at the principal cross-section have been measured for this case and, as Fig. 17 shows, the maximum intensity of stress rises to very high values at the pin, while, if this latter is a forced fit in the hole, there is a still further increase which has to be taken into account.

The problems here presented are in fact fundamental in all cases of structures which are pinned or rivetted together, and despite innumerable researches in this field, it is probably true to say that our knowledge of the stresses which occur in such cases is still very rudimentary, especially in joints where rivets are grouped together, as in boilers, bridges and other frame structures. Analysis by photo-elastic means has this advantage for such problems that stress measurements refer to a point in a plate, and can be made independent of measurements taken at any other point, but as the material used is necessarily transparent,

the usefulness of the results depends on whether these can be applied directly to an actual structure. In an earlier part of this address attention was drawn to the fact that cases occur in which the theory of the behavior of elastic materials shows that the fundamental equation of plane stress may involve elastic constants, and much attention has been given to this matter in recent years by mathematicians, especially Mitchell, Volterra,

FIG. 17.



Lines of principal stress and distributions due to a pin bearing against a central hole in a tension member.

Weingarten, Cesaro, Tedone, and others, and these researches have been critically examined and extended by Love [5] and Filon.[6]

It is not possible here to go fully into this question, but it will at least be useful to indicate by reference to an example the nature of a difficulty which presents itself here in applying the results obtained on one material limited by two or more separate boundaries to another similar body of another material. In any problem of generalized plane stress the stresses and strains must be single valued, and the latter are given by equations of the type

[5] "The Mathematical Theory of Elasticity," A. E. H. Love, Third Edition.

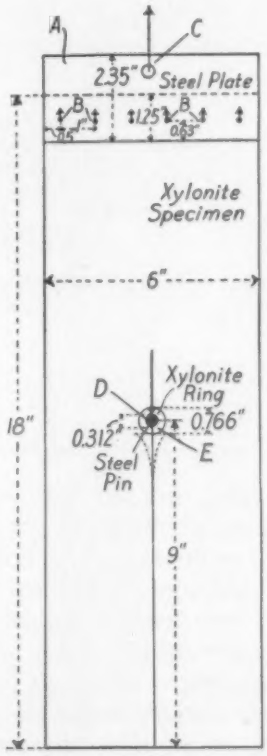
[6] "On Stresses in Multiply-connected Plates," L. N. G. Filon, Report of the Complex Stress Committee, British Association Report, 1921.

$$2\mu \cdot U = -\frac{\partial x}{\partial x} + \frac{1}{1+\eta} \cdot \frac{\partial \psi}{\partial y}$$

$$2\mu \cdot V = -\frac{\partial x}{\partial y} + \frac{1}{1+\eta} \cdot \frac{\partial \psi}{\partial x}$$

where U and V are the displacements, μ is the rigidity nodulus, η is Poisson's ratio, $\nabla^2\psi = 0$ and $\frac{\partial^2 x\psi}{\partial x.\partial y} = \nabla^2 x$. If the forces reduce to couples or to a balanced system of forces on each boundary, it can be shown that the stress distribution is independent of physi-

FIG. 18.

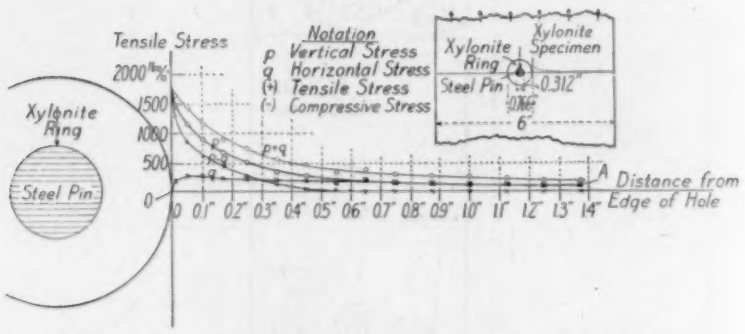


Experimental plate for the determination of the stress distribution due to the contact pressure of a pin in a centrally placed note.

cal constants, but if this condition is not fulfilled a correction is required, when the results of photo-elastic observations are applied to another material, as the combination of solutions required to ensure that the strains are one valued brings in Poisson's ratio.

In the case of a ring investigated by Filon, it is shown that if the ratio of the inner to the outer radii is nearly unity, the corrections are at the most 2 per cent., and a method of dislocation is suggested for determining the correction in any case. As the matter is of importance, I may refer briefly to some experiments which have been made of a pin bearing against a hole in a very large plate (Fig. 18), in order to reduce the influence of the boundaries as much as possible. The upper edge of this tension member was secured by a pair of steel plates *A* by six small bolts *B* arranged symmetrically with reference to a centrally placed hole *C* for the reception of a pin secured in the upper shackle of a testing machine. The lower shackle was connected to the plate

FIG. 19.



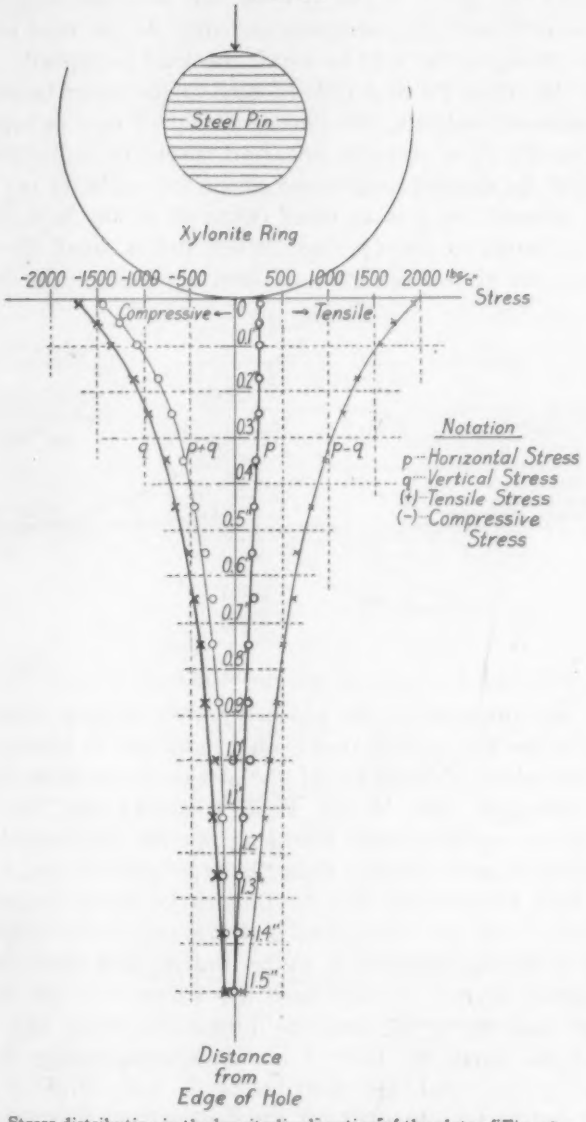
Stress distribution in a wide plate at a cross-section through the central pin.

by a pair of long thin links, with pin ends passing over a steel pin *D* of 0.312 inch diameter, secured centrally in a transparent ring *E* of the same material as the plate, and turned to fit the hole.

The effect of a central core of steel upon the distribution of the stress given by the ring bearing against the hole is probably to cause a somewhat higher contact stress immediately in the line of the applied load than might otherwise be obtained if the pin were wholly of the same material as the plate, but, as will appear, the experimental results do not show any exceptional rise of normal pressure toward the line of load and is in this case, and also in others, found to be very constant for a considerable arc on each side of the central line.

The measurements of stress distribution, as made by Mr. T. Fukuda, one of my research students, show that at the cross-section through the centre of the pin the tensional stress p (Fig.

FIG. 20.



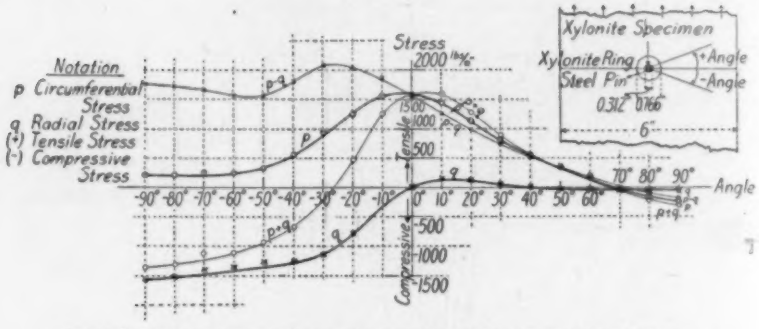
Stress distribution in the longitudinal section of the plate of Fig. 18.

19) rises to a maximum of about 1500 pounds per square inch for an applied mean stress of 180 pounds per square inch on this cross-section.

Beyond the point A the stresses are so small that they are not measurable with any accuracy and they do not tend to become uniform owing to the way in which the load is applied. Assuming that the stress curve p falls to zero at the outer boundary, as the experiments indicate, this part of the curve may be represented approximately by a straight line, and with this assumption it is found that the applied load is accounted for within 3 per cent.

The cross-stress q is as usual obtained as the half difference of the ordinates of the $(p \pm q)$ curves and is small throughout, and moreover shows no trace of lateral pinch at the boundary

FIG. 21.



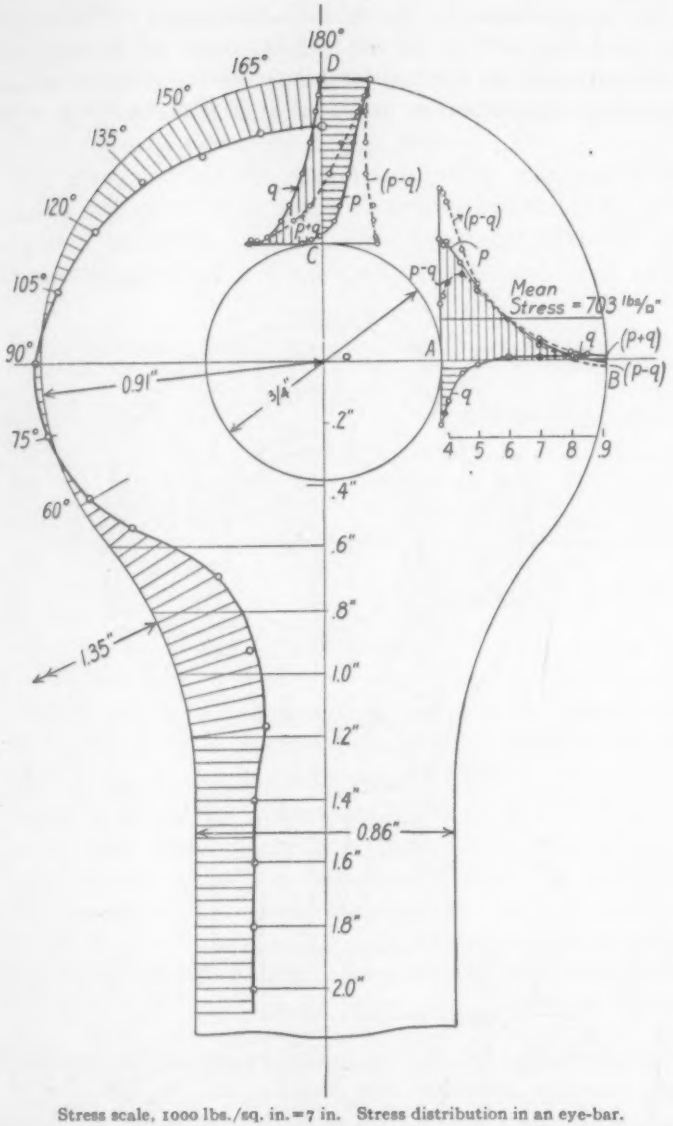
Stress distribution on a circle .01 inch larger in radius than the pin of Fig. 18.

point O, due probably to the pin being very slightly smaller than the hole, while the applied load is only moderate in amount.

A mathematical analysis of the stress distribution by a university colleague, Mr. W. G. Bickley, shows that the p stress distributions are practically identical, but the theoretical q stress distribution is much smaller than the experimental one, a discrepancy which is probably due to this curve being found as the difference of two sets of stresses both comparatively large in comparison with the quantity q to be found, and each subject to experimental error. In this case the value of η for the nitrocellulose used is .3754, and the terms involving this physical constant are small, so that if $\eta = .25$ corresponding to a steel member is employed, the distribution is only slightly affected. Similar results are obtained for the distribution along the central line shown in Fig. 20.

In this example it is not possible to measure the sum of the principal stresses exactly at the contour of the hole, as the measur-

FIG. 22.

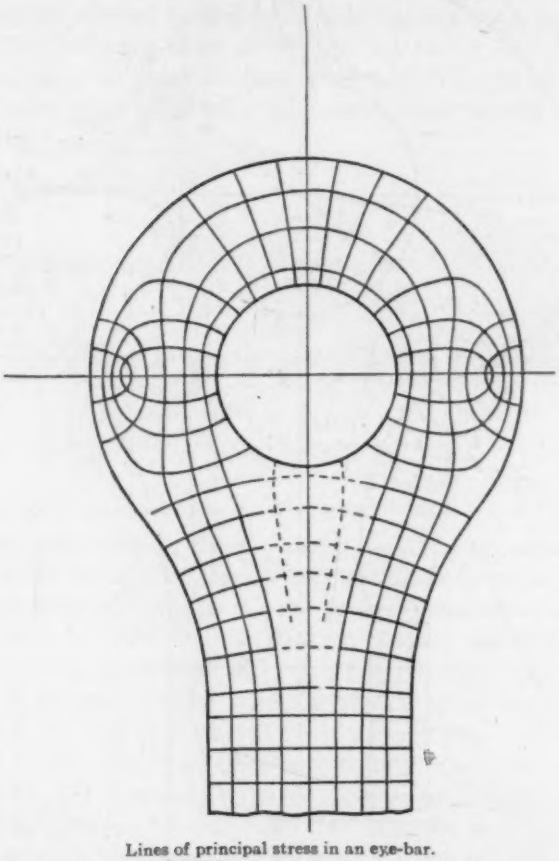


Stress scale, 1000 lbs./sq. in.=7 in. Stress distribution in an eye-bar.

ing needles will not register exactly on the boundary, and although optical measurements can be made at the contour, these are not of themselves sufficient in this form of measurement to give the

distribution unless observations are made of the isoclinic bands to effect a separation of the stress constituents. The measurements recorded on Fig. 21 are therefore for points on a circle .01 inch larger than the hole boundary, and for this contour the radial stress q is found, as indicated in Fig. 21, to be a very flat

FIG. 23.



Lines of principal stress in an eye-bar.

curve immediately over the pin falling to zero at the points where the cross-section intersects the contour, and beyond this it has a small tensional value which ultimately becomes an insignificant compression.

The uniformity of radial compression stress over a considerable arc on each side of the line of pull is of interest, since the

method of applying the load by a central steel core bearing upon a nitrocellulose ring seems to offer an opportunity of developing a high peak in the stress curve at the line of load, but other examples, one of which will be referred to, confirm the view that this contact distribution is very uniform over the pin for an arc of about 30° on each side of the line of pull.

The general result of this investigation in an unfavorable case is, therefore, to show that the results of photo-elastic investigation may be safely used to bodies of similar shape in metals, where an accuracy of ± 5 per cent. is sufficient, as it probably

TABLE VII.

Stress Distribution along Horizontal Section AB through Centre of Pin.

Distance from Centre of Pin. Inches.	Stresses in Lbs./Sq. In.				p_m = Mean Stress across Section.
	$p+q$	$p-q$	p	q	
.38	920	2960	1940	−1020	
.39	1030	2700	1865	−835	
.40	1260	2570	1915	−655	Tension + compression −
.45	1400	1800	1600	−200	p_m = 683 lbs./sq. in. measured.
.50	1140	1250	1195	−55	Load = 147 lbs.
.60	790	660	725	+65	p_m = 703 lbs./sq. in. applied.
.70	340	250	295	+45	Error = −2.9 per cent.
.80	160	0	80	+80	
.85	50	−20	−15	+35	

is in most cases of engineering application with materials whose physical properties in bulk cannot be guaranteed more closely. It is of interest in conclusion to refer to another example of engineering practice of the same type, the stress distribution in eyebars, as these have in the past been extensively used in the construction of long-span bridges, although the tendency of modern practice is to restrict their use as much as possible. It is, however, quite possible that in an exceptionally large bridge such elements may be found to be necessary, and an examination of the stress distribution in one form may therefore be of interest.

For this purpose any standard form will serve as an illustration, such as the model having the dimensions of Fig. 22, and stressed by a steel cored pin, as in the last example, giving a stress picture. In this example it will be noted that the high stress intensity at the pin in the line of the cross-section falls very rapidly until it reaches a zero value near the outer contour,

at which latter a small compression stress is developed, a result which is confirmed both by the measurements of the stress dis-

TABLE VIII.

Eye-bar.

Stress Distribution along Vertical Section CD through Centre of Pin.

Distance from Centre of Pin. Inches.	Stresses in Lbs./Sq. In.			
	$p+q$	$p-q$	p	q
.38	−1480	900	−290	−1190
.39	−1140	890	−125	−1015
.40	−880	860	−10	−860
.45	−450	840	+195	−645
.50	−180	830	+325	−505
.60	+120	710	+415	−295
.70	+320	710	+515	−195
.80	+600	710	+655	−55
.85	+720	740	+730	−10
.90	+780	800	+790	−10

tribution, Fig. 22 and Table VII, and also by the lines of principal stress, Fig. 23. In the former curves the error of the measure-

TABLE IX.

Eye-bar.

Stresses in External Contour.

y Inches.	θ Degrees.	Stress $p-q$ Lbs./Sq. In.
2.0	—	930
1.8	—	930
1.6	—	955
1.2	—	1225
1.0	—	1200
.8	—	1225
.6	—	490
—	60°	172
—	75°	−25
—	90°	−49
—	105°	122
—	120°	366
—	135°	440
—	150°	734
—	165°	734
—	180°	800

ments is estimated by integrating the stress across the transverse section and comparing it with the total net pull of 147 pounds, as is shown, this table giving an error of −2.9 per cent.

It is of interest to note that the lateral pinch is very large here and that the contact stress around the pin is of the same type as in the earlier case, but the flatness of the curve of distribution over the crown of the pin is even more pronounced and so much so as to indicate that the bending action of the load upon the upper curved part of the member tends to throw slightly more contact stress on the sides than at the centre, but with more material suitably disposed above the pin this tendency can be diminished. The stress measurements at the vertical section *CD* are also included here, Table VIII, and prove to be moderate in amount. They are in fact never so great as the maximum stress at the external contour, Table IX, near the joint of the straight and curved parts of the link. All these values are plotted in Fig. 22.

If it were necessary it would not be difficult to design a form of head for an eye-bar which would give the maximum possible strength at the end, and indeed the help which photo-elasticity can give to engineers in this and many other ways has, I hope, been made clear by the consideration of these few problems of contact stress.

Atomic Weight of Holmium.—FRANK H. DRIGGS and B. S. HOPKINS, of the University of Illinois (*Jour. Am. Chem. Soc.*, 1925, xlvii, 363–369), have determined the atomic weight of holmium by means of the ratio of holmium trichloride to silver. Six determinations gave values ranging from 163.43 to 163.54, the average value being 163.47. J. S. H.

Strains on Stadium during Progress of Game.—Added stresses in the steel reinforcement of a concrete stadium due to the vigorous enthusiasm of the crowd were measured during a recent game by means of the carbon resistance strain gages developed by the Bureau of Standards, Department of Commerce.

Such mass movement, it has long been known, may increase the live load on the structure far beyond that caused by the people when sitting or standing still or moving at random, but until recently it has not been possible to obtain an accurate record of such sudden changes of stress. In this particular test the live load when the crowd was still was found to increase the stress in the steel by about 1000 pounds per square inch, whereas 4000 pounds would have been considered safe. Under the worst conditions occurring during the course of the game, the movements of the crowd sometimes gave an additional 300 pounds per square inch. It is pointed out, however, that the worst conditions from the point of view of safety arise when

the crowd, in stamping rhythmically, happens to strike the natural vibration period of the structure. It has been reported that under these conditions the stress has exceeded the static live load by as much as 150 per cent.

In making the test the concrete was removed from the reinforcement over short lengths, and the gages were attached directly to the steel. After the test the holes were concreted over again. A gage of this type depends for its operation on the fact that stacks of carbon rings undergo a change in resistance with change in pressure. It is so arranged that a small change in the distance between the points of attachment to the structure causes a change in the pressures on two of these carbon stacks, the pressure on one being reduced while that on the other is increased. The change in distance is caused by a change in the load carried by the steel. This gage is connected by three electric wires to the indicating or recording device, and these wires may be of any desired length. Changes of load are followed very rapidly, and those lasting only a fraction of a second can be recorded as well as changes of longer duration. H. L.

Hydroxylamine.—CHARLES DE WITT HURD and H. J. BROWNSTEIN (*Jour. Am. Chem. Soc.*, 1925, xlvii, 67–69) have isolated free hydroxylamine by crystallization from its solution in redistilled butyl alcohol. In their process, dry hydroxylamine hydrochloride reacts with sodium butylate in the presence of butyl alcohol which has a boiling point of 115.5° to 117.5° C. Hydroxylamine is liberated and dissolves in the butyl alcohol, while sodium chloride precipitates and is removed by filtration. The solution of hydroxylamine in butyl alcohol is cooled to a temperature of −10° C. Large white crystalline flakes of hydroxylamine deposit are collected on a filter, washed with ether, and finally kept at the temperature of a refrigerator in a stoppered tube. The actual yield of hydroxylamine is 50 per cent. of the amount actually formed in the reaction. The remainder may readily be recovered from the mother liquor, the butyl alcohol filtrate, *e.g.*, as hydroxylamine hydrochloride. J. S. H.

Butternut Syrup.—According to PAUL A. HERBERT (*Quarterly Bull. Agric. Exp. Sta.*, Michigan Agricultural College, 1924, vii, 62–63), the sap of the butternut, *Juglans cinerea*, contains 0.26 per cent. invert sugar and 2.10 per cent. sucrose, and yields a syrup on "boiling down." This syrup has the same characteristic flavor as maple syrup. Butternut sap begins to run a few days before that of the sugar maple, and continues at a fairly uniform rate throughout the sugaring season. The yield of sap is only 6 per cent. less than that obtained from a maple of the same diameter and crown development. Upon concentration of the sap, a jelly separates, containing pectin, water, and a small amount of sugar. This jelly must be removed in the manufacture of a clear syrup or sugar. A good quality syrup may also be obtained from the sap of the walnut.

J. S. H.

MAGNETIC PROPERTIES OF THE FIFTY PER CENT. IRON-NICKEL ALLOY.*

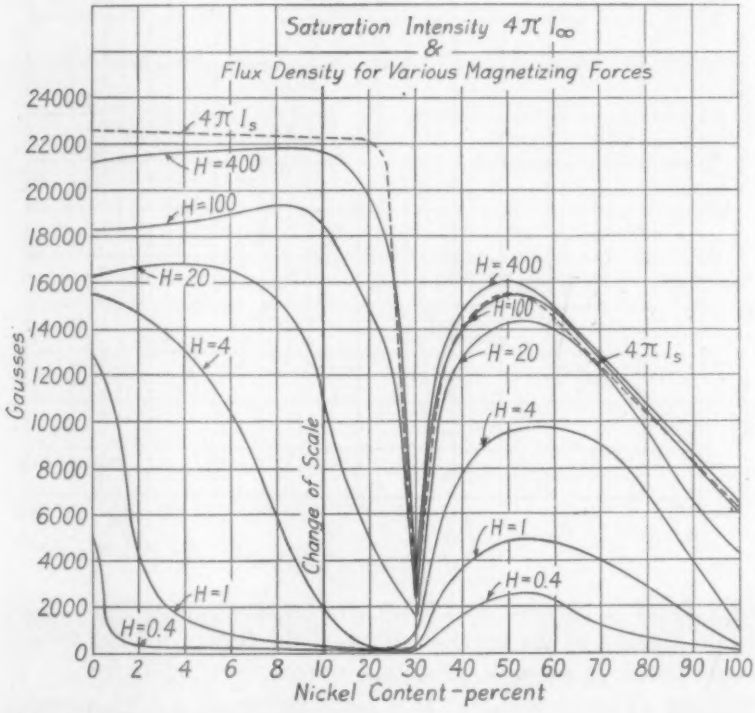
BY

T. D. YENSEN, E.E.

The Westinghouse Electric and Manufacturing Company.

THE two ferromagnetic elements, iron and nickel, form a continuous series of solid solutions from zero per cent. Ni to zero per cent. Fe. In going from one end of the series to the other, alloys

FIG. 1.

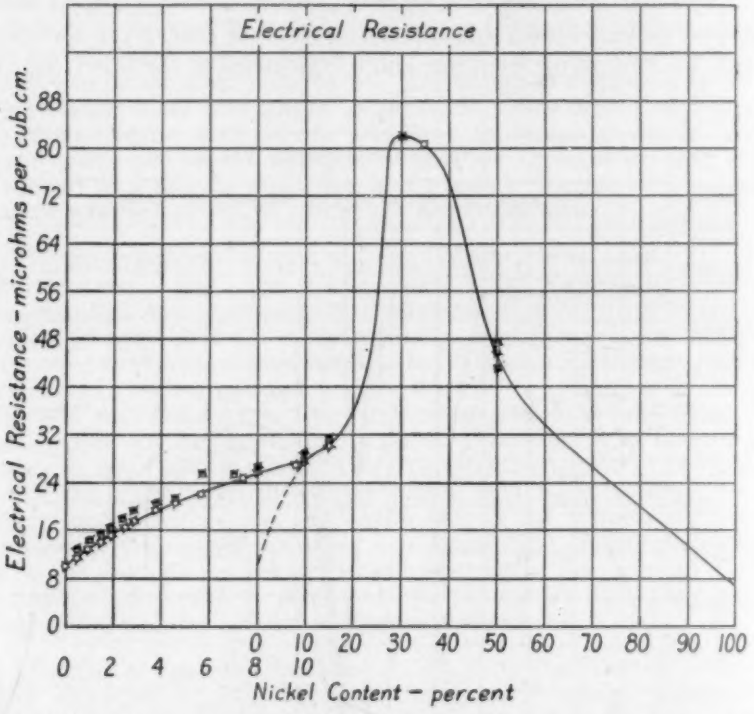


with almost any conceivable physical property may be encountered. For mechanical purposes materials may be found from those that are soft, ductile and weak to those that are hard and strong

* Address delivered Friday, September 19, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

and with all gradations in between. If a material with a certain coefficient of thermal expansion is wanted, some Fe-Ni alloy will probably answer the purpose. The electrical resistance assumes all values from 7 to over 80 michroms. As for magnetic properties, the series offers variations from nearly non-magnetic alloys to those with a higher permeability than that of pure iron. And

FIG. 2.

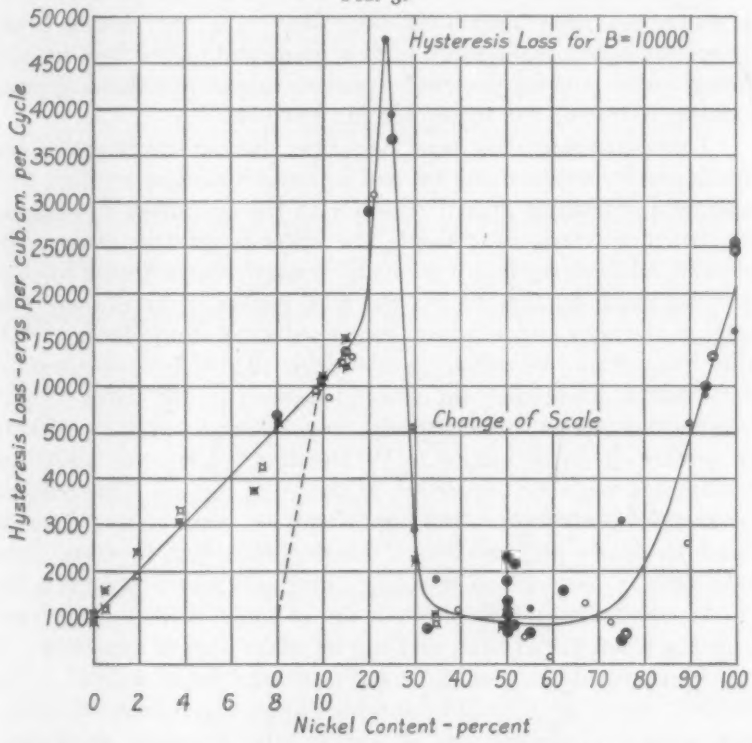


not only is it possible to obtain these various properties singly but on account of the peculiar shape of the curves for the various properties, it is possible to obtain numerous combinations. To illustrate (Figs. 1 and 2): If a combination of a high electrical resistance and a high magnetic permeability is desired, an alloy with 40–50 per cent. Ni would be selected, whereas if a combination of a high electrical resistance and a low magnetic permeability is looked for, the 30 per cent. alloy would be selected. Furthermore, the properties of these alloys are subject to heat treatment

to a very large extent, so that there is practically no limit to the combinations obtainable. If the cost of nickel can be still further reduced, these alloys will undoubtedly be used to a far greater extent than at present, especially for magnetic purposes.

The magnetic properties of the iron-nickel alloys were studied by Burgess and Aston in 1910,[1] and in 1920, the writer presented

FIG. 3.



a paper before the American Institute for Electrical Engineers,[2] giving the magnetic and electrical properties of the complete series of alloys annealed at 900°, followed by slow cooling. Figs. 1, 2 and 3 have been reproduced from this paper. Fig. 3 (hysteresis loss) shows a great deal of deviation from the curve in the region of 50 per cent. nickel, depending upon small amounts of addition agents used like Mn, Si, Ti or Al. This was also true in the

[1] *Metall. Chem. Eng.*, **8**, p. 23 (Jan., 1910).

[2] *Trans. A.I.E.E.*, **39**, I, p. 791 (1920).

case of the permeability for low magnetizing forces, showing that these alloys are quite susceptible to variations in the third element, that has to be added to make the alloy forgeable. The best result was obtained with samples machined from the ingot without forging and containing no third element. Of the various addition agents, only Mn and Ti make the alloy forgeable, and of these two, Mn produces by far the better magnetic properties. The advantage of this alloy over pure iron is a very much lower hysteresis loss, considerably higher permeability for low magnetizing forces, and an electrical resistance about five times greater, making it useful for many specific purposes.

This particular alloy was, therefore, further investigated and developed for commercial use and is now a standard product with magnetic properties greatly superior to the best alloy reported in the paper referred to. While the alloy is greatly affected by metallic addition agents, it seems to be even more affected by oxygen, so much so that to get the best results, it is necessary to prepare the alloy and to anneal it in a reducing atmosphere, preferably hydrogen. Annealing in hydrogen at a high temperature is particularly essential if the alloy is desired in the form of thin laminations, as it is practically impossible to roll it without subjecting it to oxidation. When thus made, the alloy has remarkable magnetic properties, as shown in Fig. 4. This particular sample consisting of ring punchings 0.35 mm. (0.014″) thick, has a maximum permeability of 82,000 (H = 0.05, B = 4100) and a hysteresis loss of 220 ergs per cubic centimetre per cycle for B = 10,000 gausses. The alloy is easily made, readily forged and rolled at a bright red heat, and can be cold rolled if necessary. It can be punched without difficulty into any shape desired. The finished punchings should be annealed in an atmosphere of hydrogen or other reducing gas at atmospheric pressure, or slightly above, at a temperature of 1000 to 1100° C. for eight to ten hours and cooled at any convenient rate.

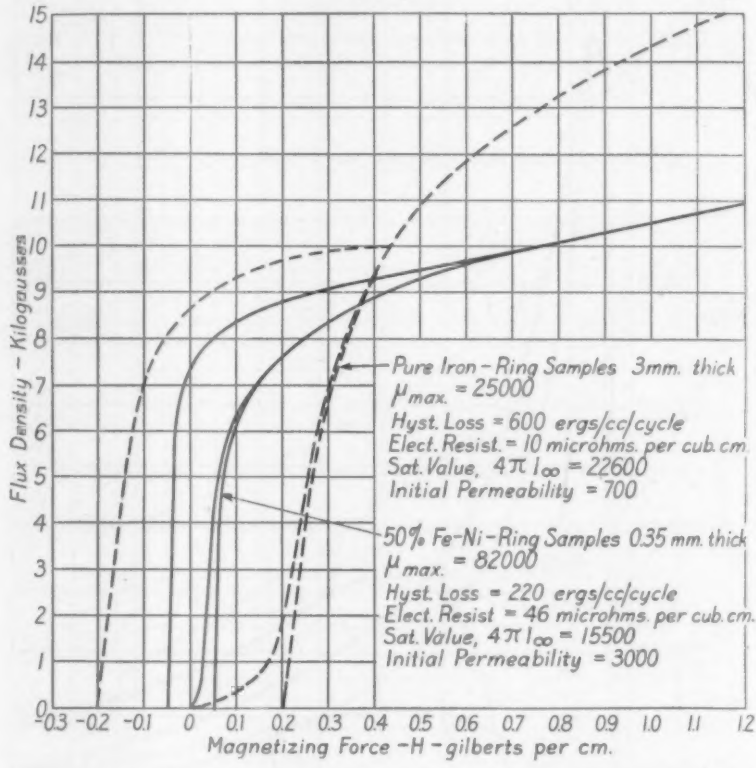
COMPARISON WITH OTHER MATERIALS.

In April, 1923, a very interesting paper was presented before the American Physical Society by H. D. Arnold and C. W. Elmen,[3] describing the remarkable magnetic properties of the 78 per cent. Ni alloy. The chief peculiarity of this alloy—and of

[3] JOUR. FRANK. INST., 195, 5, p. 621 (May, 1923).

all the alloys in the region of 60 to 80 per cent. Ni—is that the alloy, in order to exhibit these good magnetic properties, must be cooled quickly from the magnetic transformation point, which in the case of the 78 per cent. alloy is about 625° C. In order to perform this cooling rapidly enough, the alloy must be in the

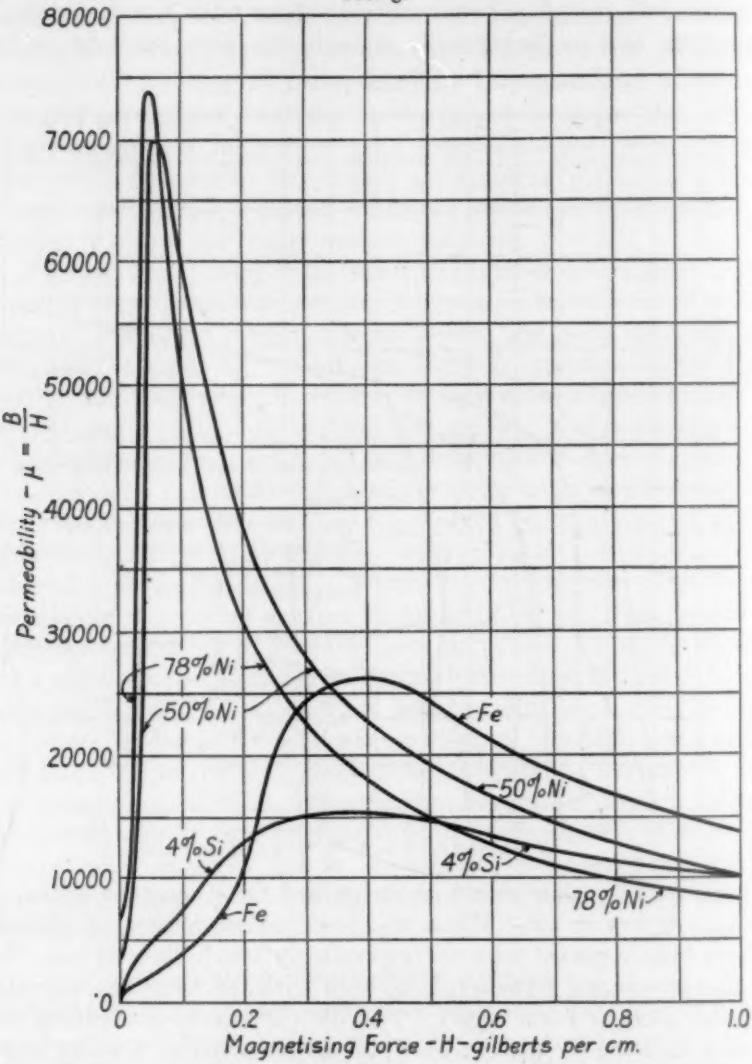
FIG. 4.


Flux Density – Kilogausses
Magnetizing Force –H– gilberts per cm.
Pure Iron – Ring Samples 3mm. thick
μ max. = 25000
Hyst. Loss = 600 ergs/cc/cycle
Elect. Resist. = 10 microhms. per cub. cm.
Sat. Value, 4π I∞ = 22600
Initial Permeability = 700
50% Fe-Ni – Ring Samples 0.35 mm. thick
μ max. = 82000
Hyst. Loss = 220 ergs/cc/cycle
Elect. Resist = 46 microhms. per cub. cm.
Sat. Value, 4π I∞ = 15500
Initial Permeability = 3000

form of very thin sheets or strips and these must be cooled in single layers in air. When so cooled permeabilities of 100,000 have been reported with correspondingly low hysteresis loss. Its chief advantage, however, is its high initial permeability, reported to be 9000 or even higher. For the purpose of comparing this alloy with the 50 per cent. alloy, the writer prepared a 25-kg. ingot of the 78 per cent. alloy in a high-frequency furnace, using the same grade of materials and the same method of melting as were used for the 50 per cent. alloy. The ingot was forged into billets

and rolled to 0.125, or 0.25 and 0.35 mm. (0.005", 0.010" and 0.014") thick strips, from which ring punchings 4.5 cm. × 3.17

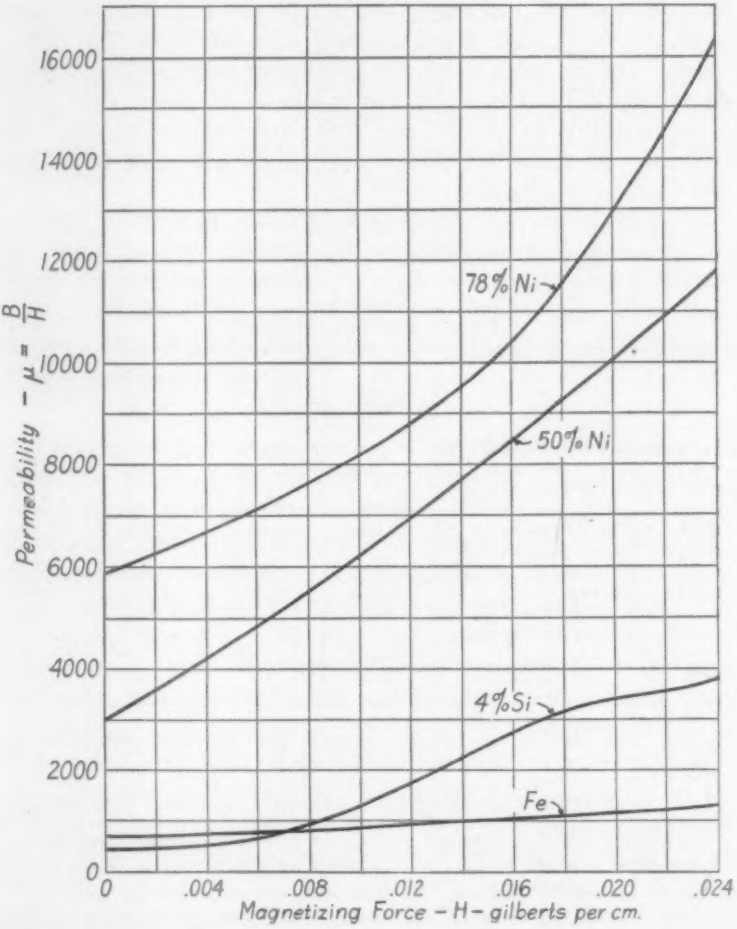
FIG. 5.



cm. (1¾" × 1¼") were punched. These punchings were then annealed at 900° in vacuum one hour, slowly cooled to 625°, held there for fifteen minutes, during which time the furnace was

filled with nitrogen, and then quickly removed from the furnace and cooled in air. To accomplish the cooling quickly the punchings were supported about 2 cm. apart by means of fine Ni wires, so that each sample could be handled as a unit. After withdraw-

FIG. 6.



ing the samples from the furnace, they were swung in the air, so that the cooling from 625° to 300° occupied only a few seconds.

The 0.35 and 0.25 mm. punchings gave about the same results, while the 0.125 mm. punchings were not quite as good, so that comparisons have been limited to the former. Comparative data

have also been obtained for 4 per cent. Fe-Si alloys [4] in the form of 0.35 mm. (14 mil) ring punchings and for pure iron in the form of rings 3.8 cm. × 3.17 cm. × 1.19 cm. (1½" × 1¼" × ¾"). Permeability curves for these materials are shown in Figs. 5 and 6, Fig. 6 giving the permeabilities for very low values of H. From these curves the superiority of the 78 per cent. alloy over the 50 per cent. alloy for extremely low magnetizing forces is evident. On the other hand, the maximum permeability is practically the same for both, and for values of H above 0.05 gilbert the permeability of the 50 per cent. alloy is the higher. The superiority of these Ni alloys over pure iron and high-grade Fe-Si [5] alloys is apparent.

In addition to the characteristics mentioned above, Table I gives a summary of the related characteristics of these four mate-

TABLE I.

Various Materials Compared.

	Fe 3 mm. Thick.	4 p.c. Si 0.35 mm. Thick.	50 p.c. Ni 0.35 mm. Thick.	78 p.c. Ni 0.35 mm. Thick.
Initial permeability—(B/H) H =0	700	440	3,000	5,850
Maximum permeability—(B/H) max.	26,000	15,500	70,000	74,000
Saturation value, 4 I (gausses)	22,600	20,000	15,500	10,500
Hysteresis loss (ergs/c.c./cycle for B = 10,000)	600	500	220	200
Retentivity (gausses)	8,600	5,200	7,300	5,500
Coercive force, gilberts per cm.	0.20	0.15	0.05	0.05
Electrical resistance, michroms/c.c. for 20° C.	10	55	46	21
Density	7.9	7.6	8.3	8.6

rials so that the alloy most suitable for specific purposes can be selected.

It is seen from this table that, except for initial permeability,

[4] Containing less than 0.01 per cent. C and less than 0.01 per cent. Si.

[5] Attention is called to the peculiar shape of the curve for 4 per cent. Si and for H between 0 and 0.2. If data were not obtained for values of H below 0.02 gilbert the curve would indicate an initial permeability of about 3000, whereas there is a decided falling off of the curve between 0.02 and 0.01, so much so that the actual initial permeability is only 440. The data were checked both with a.c. and d.c. so that it is very improbable that the peculiar shape is due to errors in testing. It is perhaps a characteristic due to the presence of a non-magnetic element (Si) interfering *with the susceptibility of the atoms to very low magnetizing forces.*

the 50 per cent. alloy is equal to or better than the 78 per cent. alloy. It has 50 per cent. higher saturation value and over double the electrical resistance, the latter property being particularly valuable in connection with alternating or oscillating currents. High initial permeability is, of course, very effective for purposes employing extremely feeble magnetizing forces for the production of signals and other effects such as distributed inductance in submarine cables, and for such cases the 78 per cent. alloy is no doubt the best material known. It is possible that the results given above are not the best obtainable, as Arnold and Elmen reported values higher than those given in this paper. This may be partly due to the form of the test samples, but as the same form was used in this case for both alloys, the results are strictly comparable. Where high initial permeability is of paramount importance, the 78 per cent. alloy is therefore the best alloy to use, while the 50 per cent. alloy may be the better where other characteristics are of importance.

CONCLUSIONS.

The remarkable magnetic properties obtained with these two alloys, the 50 per cent. and 78 per cent. Ni alloys, confirm the writer's previous experience with iron-silicon alloys, namely, the magnetic properties of materials in general are very susceptible either to minute variations in composition or small variations in heat treatment or both, and results obtained with a single series of alloys prepared in one way and annealed according to one method, may give only the slightest indication of properties obtainable with apparently the same alloys prepared and treated in a slightly different way. Prior to the development of the vacuum-liquid air method of carbon analysis [6] it was very difficult to distinguish by chemical analysis between an iron-silicon alloy having a maximum permeability of 5000 and 50,000. A difference in carbon content of less than 0.01 per cent. has been found sufficient to account for this difference in magnetic properties. Arnold and Elmen's 78 per cent. Ni alloy with initial permeabilities of 5 to 10,000 require air quenching from the A_2 transformation point. (It would be interesting to know by what process this fact was revealed.) And now we have the 50 per

[6] *Amer. Electrochem. Soc.*, **37**, p. 227 (1920); *Jour. A.I.E.E.*, **43**, p. 558 (June, 1924).

cent. Ni alloy that by a mere modification in the annealing treatment can be transformed from an alloy with ordinary magnetic properties to one with quite extraordinary ones. By concentrating on other Fe-Ni alloys, it will undoubtedly be found that similar improvements can be obtained.

In the case of the Fe-Si and the 50 per cent. Ni alloys, the improvement is primarily due to minute changes in composition—dissolved carbon in one case, and probably oxygen in the other—while in the case of the 78 per cent. Ni alloy, the improvement is more probably due to the retaining at room temperature of the atomic structure existing at the magnetic transformation point. In any case, the ultimate cause is probably one connected with the atomic structure, and when the exact mechanism producing magnetism shall have been disclosed, it will perhaps be possible to predict the composition to give certain properties as well as the properties to be expected from certain compositions.

Annual Report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution. L. A. BAUER, Director, and J. A. FLEMING, Assistant Director.—The period covered is from November 1, 1923, to June 30, 1924, and, as is true for all previous reports of the Department, it is impossible for an understanding citizen of the United States to read it without a feeling of pride that so fine a scientific enterprise flourishes in his country. There is, moreover, mingled with the relation of achievement in measurement no mere trace of romance and of adventure. Observer Howard ascending the Paru River in Brazil passed more than fifty rapids and pressed on until his Indian guides refused to go further on account of their superstitious fear of the dangers ahead. To turn from equatorial to polar regions, Observer Goddard passed the time covered by this report on the west coast of Greenland, while observations are continued on the vessel *Maud* of Amundsen's Arctic expedition in the ice north of Siberia. In the Straits Settlement and also in French Indo-China the horizontal component of the earth's magnetic field was found to exceed .400 c.g.s. unit. No other places are known to have as large values.

Much thought is now given to the determination of the secular variation of terrestrial magnetism both on land and sea. In addition to the practical importance of such work, its significance for the theory of the earth's magnetic field is of high importance. Perhaps the *Carnegie* will resume her voyages. G. F. S.

SPECTROSCOPY IN THE INFRA-RED REGION OF THE SPECTRUM.*

BY

PROFESSOR AUGUSTUS TROWBRIDGE, Ph.D.

Member of the Institute; Princeton University.

DURING the last ten years the remarkable success of predictions based on the atomic model now commonly known as the Bohr atom has interested physicists generally in what used to be a special and restricted field of their science. At present research in the field of spectroscopy holds out the greatest promise of throwing light on the question of the constitution of matter and every physicist, in no matter what field his own research activities may lie, is deeply interested in the subject of atomic structure. Very naturally the attention of those who are becoming interested in recent spectroscopic work has been drawn chiefly to the remarkable results which have been obtained in the visible, ultra-violet and X-ray regions of the spectrum where by far the greatest number of observable lines of the elements lie, and many persons not directly engaged in spectroscopic work are unaware of the extent and importance of the spectroscopic work which has been done in the long wave-length region of the spectrum. The object of this paper is to call attention to what has been done in this field.

THE INFRA-RED SPECTRUM.

Distributed over the region of wave-length greater than 8000 Ångström units lies much of the energy which reaches the surface of the earth from the sun, and the discovery of this fact was alone sufficient to stimulate research on the energy distribution of artificial light sources more than a generation ago. Furthermore, the infra-red region seemed to be one of possible great theoretical importance if one estimated its extent in terms of the wave-lengths comprised within its limits, for it appeared, when measured thus, to be far more extensive than all the rest of the spectrum. It also appeared to be very extensive when estimated in terms of vibration frequencies in the manner in which intervals are

* Address delivered Thursday, September 18, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

measured in music. Measured in this way the visible spectrum comprises one octave, the ultra-violet about two octaves, while the portion of the infra-red which has been explored step by step, is about five octaves. The whole range in which scattered observations lie is about seven octaves.

From the spectroscopic point of view the five octaves of the infra-red spectrum have proven far less interesting than the one octave of the visible region. It now appears that it is only in the first two and possibly third infra-red octaves that any significant data on atomic constitution are to be sought and that data from the remaining octaves of the region will be a source of information on molecular constitution.

The failure of the early workers in the infra-red to find it rich in series lines of the chemical elements made them turn to investigations designed to prove or disprove the then dominant electromagnetic theory of light. For this purpose the enormous extent of the spectrum was a real advantage, for it permitted the test of theoretical formulæ over a very wide range of wave-lengths. The wide extent of the spectrum was also favorable for the testing of the validity of the various radiation formulæ which had been proposed as giving the energy emitted by a black body as a function of its temperature and of the wave-length of the energy emitted.

The earliest work on the infra-red spectrum is that of Melloni in 1833. A large part of this work was designed to test whether the invisible radiations were similar to visible radiations, whether they might be reflected, refracted, polarized, etc., by means identical with those already familiar in work in the visible region. The first attempt to measure the wave-lengths of infra-red radiations was made by Moulton, who in 1879 adopted a simple interference method. This same method was adopted about ten years later by Rubens in his first studies on the dispersion of substances suitable for use as dispersing prisms in the infra-red region. To Langley (1884) is due the first accurate determination of wave-lengths by means of the diffraction grating. The grating was used by Langley and his contemporaries merely in order to determine the dispersion of prism substances, and prisms calibrated in this manner were used to produce the spectrum in their experimental investigations. It thus happened that in the work of Langley and in most of the early work of Rubens, Paschen and their respective

co-workers, the dispersion and the resolving power of the spectrometers used were very small, and in compensation the energy concentration in the spectra was relatively great. These conditions were favorable for exploration work in a new and very extensive field but were, of course, very unfavorable for detecting sharp emission or absorption lines or for studying the structure of bands. As detecting instruments, thermopiles and bolometers were used, and it was mechanically impossible to make these sufficiently narrow to prevent them from covering a large wave-length interval in the spectrum.

To illustrate the progress in improving working conditions made during the last thirty years, the following comparison is very striking: In 1893 Ångström, in an important piece of work on the absorption band of HCl in the second octave of the infra-red spectrum, used a measuring instrument which covered a wave-length interval of 4000 Ångström units. In a recent piece of work on the same absorption band Imes used a measuring instrument which covered 29 Ångström units and was able to show a fine structure in the band which wholly escaped analysis with the grosser methods of thirty years ago. However, it should be remembered that even our present resolving power in the infra-red spectrum is exceedingly feeble compared with that obtainable in the visible and ultra-violet regions. It is true that for a portion of the first octave of the infra-red, it has been found possible to employ photographic methods and thus obtain resolving powers comparable with those in the visible but, in general, accurate work in spectroscopy in the long wave-length region is handicapped for want of some energy integrating measuring device in place of the thermopile or bolometer habitually used.

The early spectroscopic apparatus of low resolving power was well suited to the task of testing the predictions of the electromagnetic theory of light. Rubens, Paschen and others in the nineties of the last century did very useful work in testing the validity of the dispersion formulæ of the Kettler-Helmholtz type over a very wide range of wave-lengths and about the same time the discovery of the recurrent features of the complete dispersion curve of quartz by E. F. Nichols was not only a very striking verification of the validity of the dispersion formula, but also had as a practical result the perfection of the method of residual

rays. This method in turn served to furnish data on the free periods of vibration of certain chemical molecules.

In 1903 Rubens and Hagen obtained a striking verification of a prediction of the electromagnetic theory of light that the optical reflecting power of a metal mirror should be calculable from the electrical conductivity of the metal from which the mirror was made. Previous experiments in the visible region of the spectrum had not been in accord with theory and Rubens and Hagen's work showed that the theory was adequate provided that the frequency of the light reflected by the mirror was not greater than a certain amount. In 1898, using the method of residual rays, Rubens and Nichols showed that as regards state of polarization of infra-red rays reflected from a series of metal resonators of known dimensions, the prediction of the electromagnetic theory was correct. This experiment was of interest at that time because it was a repetition with light of a well-known experiment which had been made with electromagnetic waves from a Hertz oscillator.

When we consider the importance at the present time of the Quantum Theory, it is perhaps not too much to say that one of the most important pieces of research since 1900 was the verification of Planck's radiation formula by Rubens and Kurlbaum in 1901. A conclusive test of the formula was only possible throughout a very wide range of wave-lengths and over a very extended range of temperature of the emitting black body. The experimental results were obtained by infra-red methods and were found to be in agreement with the Planck formula and in definite disagreement with all other theoretical formulæ, although data obtained in the visible spectrum were insufficient to decide between them. It was the verification of Planck's formula, based as it was on the idea of quanta, which furnished the incentive to theoretical physicists to apply the idea of quanta to the problem of radiation of light by the atom. The success of this application of the idea of quanta has been phenomenal and seems likely to lead us to a new and probably more satisfactory theory of light.

SERIES LINES IN THE INFRA-RED SPECTRUM.

Although as early as 1866 investigations were begun in this field and from that date until 1895 numerous papers appeared on the subject, no systematic search for infra-red members of series

discovered in the visible and ultra-violet regions had been made under the best available conditions of resolving power. In 1895, Lehman made such a search in the case of the alkalies, the alkaline earths and of iron as far as the wave-length 9000 Ångström units. And about the same time E. P. Lewis investigated as far as 11,512 Ångström units and discovered thirteen lines due to various elements. These two papers mark the beginning of a new phase of investigation in this region. The work of Lewis set a very high standard of accuracy and showed that it was possible to employ diffraction gratings directly in this region and that the high resolving power obtained in their use very well repaid the effort when series relationships were being sought. The results of Lehman interested Paschen in this field of investigation, and it is to Paschen that we are indebted for many of the very accurate data which we possess not only in the infra-red, but also throughout the entire spectrum with which the constants of the series formulæ have been determined.

In 1904, F. A. Saunders published a paper on the series lines of cæsium, in which he showed the existence of a new series of this element with lines in the infra-red. These lines were definitely not infra-red members of series already discovered in the visible spectrum. The work begun by Saunders was extended by Bergmann in 1907 as far as the wave-length 15,000 Ångström units and the discovery of the new series by Saunders was confirmed and new lines belonging to it discovered. The series came to be called the Bergmann series and was found to be existent in the spectra of many other elements than cæsium. When, a few years ago, the older nomenclature, *i.e.*, Principal, Sharp, Diffuse, etc., for the various series came to be abandoned by writers on spectroscopy, the " Bergmann " series was called the " F " series. It should be remembered that the F series in the case of elements other than the alkalies does not lie in the infra-red spectrum. It was discovered in the case of an element for which it happens to lie in the infra-red.

The discovery of the F series had a greater influence on the development of the existing theory of atomic structure than might at first be supposed from a perusal of the literature of spectroscopy; previous to the discovery of the F series certain relationships had been found to exist between the other three series, the

P, the S, and the D series. All three series converge toward heads, *i.e.*, the spacing of the lines when plotted in wave numbers grew shorter and shorter and approached a certain wave number called the head of the series. Except in the cases of hydrogen and the alkali metals, the head was not observable with any degree of accuracy, but could be calculated accurately from the spacing of neighboring lines of the series. One of the relationships between the different series was that in the difference in the wave numbers of the heads of the P and S series was the wave number of the first member of the P series. Also that the heads of the S and D series were coincident. When the fourth or Fundamental F series was investigated, it was found that the same relationships existed between the F and D series which had been discovered to hold between the S and P series, *viz.*, the difference in wave numbers of the heads of the D and F series was equal to the wave number of the first member of the D series. Thus with the discovery of the fourth or F series there were found to exist two groups of two related series related to each other in the same way. Quite recently the existence of two new series, the G and H, has been discovered and the lines of these appear to be due to electron shifts in orbits still more remote from the centre of the atom.

In another way also the discovery by Saunders of the F series was of importance in moulding the theory of atomic structure so as to account for the series relationships observed in the spectra of the chemical elements. It had been noted that certain lines obviously belonging to a given element did not fall into any one of the series of the element. A large number of these lines had been found to have wave numbers such that they might be accounted for as combinations of terms of one series with terms of one of the other series of the same element, but even after forming all possible combinations of the terms of the P, S and D series there remained over certain lines observed but not predicted. The discovery of the F series gave new possibilities of combination lines between the F series terms and those of the other three series and many of the observed lines were accounted for in this manner.

Thus from at least two points of view, the discovery of the F series (originally discovered as an infra-red series) furnished a new series of relationships which at one and the same time guided

the setting up of the existing theory of atomic structure and put the theory to a severe test as the new F series relationships were discovered in the chemical elements of the higher groups.

BAND SPECTRA.

It is generally held that band spectra are caused chiefly by the emission or absorption of the molecule rather than the atoms of an emitting or absorbing gas, and it was recognized many years ago that there was a regularity in the lines forming the band. In fact, the regularity in a band is far more striking to the eye than is the regularity in spacing of the lines which form one of the series treated in the preceding paragraphs.

There are a number of significant differences between the structure of a series due to atomic lines and that of a molecular band. For example, the head of an atomic line series always lies to the ultra-violet edge of the series while the limit toward which the individual lines of a band approach may lie either toward the long or the short wave-lengths. In fact, this head of the band more often lies to the infra than toward the ultra edge of the series. Generally in a band there are present several groups of bands, and the individual lines which form these groups increase in intensity as the head of the group is approached.

Between the years 1869 and 1888 attempts were made to find the constants of empirical formulæ which should give the wave-lengths of all the component lines of the various prominent bands in the visible spectrum. In the latter year Deslandres summed up the regularities hitherto observed in three so-called laws, but as these were merely empirical there was no very lively interest in testing their validity until the marked success of the Bohr theory in accounting for simple line spectra revived interest in the subject of band spectra. In 1916 Schwarzschild was able to do theoretically what Deslandres had attempted to do empirically, *i.e.*, obtain a formula which should predict the structure of band spectra. This work of Schwarzschild is merely a first step toward a theoretical solution of the problem of band spectra and more data, particularly data obtained in the infra-red region of the spectrum, are needed before further progress in this subject can be expected.

If molecules be supposed to exist in a number of stationary states in any of which they neither absorb nor radiate energy,

there will be three different ways in which they may pass from one state to another. One of the modes of transition is electronic and similar to the transition invoked to explain the production of the series lines due to the atom. The other two modes are atomic and are changes whereby the molecule may store or lose energy by a relative motion of its constituent atoms, that is, by vibrations, which may be set up between atoms and by rotation of the molecule about one or more axes. According to the molecular quantum hypothesis, energy of frequency ν may be emitted or absorbed whenever the molecule makes a transition from a state in which its total energy (rotational, vibrational and electronic) is W_1, to another state in which its total energy is W_2 and the quantitative relation between the energy change and the frequency of the emitted or absorbed radiation is assumed to be that which has been found to hold for the electronic changes within the atom when it emits the series lines of the element, *i.e.*, $W_1 - W_2 = h\nu$.

In extending the quantum theory to the case of the molecule, it is necessary not only to retain the idea that the electrons are restricted in freedom so as only to be able to occupy certain orbits, but it is necessary also to assume that only certain amplitudes of vibration and only certain states of rotation may exist. Since the total energy of the system is determined by three quantities which may take on each a series of possible values, and since light of a definite frequency ν may be emitted or absorbed whenever the total energy changes by a given amount, it is evident that the number of possible combinations between the three modes of transition may be sufficiently large to explain the complicated band spectra actually observed.

Of the three modes of transition, the electronic probably involves the greatest energy changes and thus a change within the atom may entail with it a change affecting the vibrational and the rotational state of the molecule. Even if no electronic change were to take place, a vibrational change might entail a rotational change since the former is probably a greater energy change than the latter. Furthermore, it is not necessary that all the possible energy changes of the three kinds shall all be in the same direction, and thus it would be possible that a molecule might be gaining energy through its electrons and at the same time losing energy through a change in its state of vibration or rotation or both.

The idea that the absorption or emission of a molecule is due

to a definite quantum change in the vibrational energy of the constituent atoms is contained in the original paper by Planck about the year 1900, and the idea that lines may also be due to definite quantum changes in the rotational energy of the molecule was introduced by Bjerrum about 1912. According to the latter, when the rotational energy changes by one unit, it gives rise to a frequency which in general corresponds to a line in the remote infra-red so that together with this frequency there should be emitted at least three other frequencies related to it and which correspond to lines in the shorter wave-length region of the spectrum. This prediction by Bjerrum was found to be correct by Miss von Bahr, who worked in Rubens' laboratory in 1913.

From this and subsequent work on band spectra in the infra-red, it seems that bands in this region may possibly be explained on a slightly simpler hypothesis than may be necessary in the case of bands in the visible and ultra-violet regions—that is, that of the three possible energy changes, electronic, vibrational and rotational, only the last two are necessary to cause an infra-red band.

The study of the structure of infra-red bands is therefore, from the theoretical standpoint at least, simpler than the study of band structure in the other regions of the spectrum, though unfortunately, as has been mentioned earlier, the experimental difficulties are greater and the accuracy of measurements far less, but in spite of this there is some reason to expect that we shall arrive at a satisfactory explanation of the structure of band spectra generally through experimentation on the simpler, though still actually very complex, bands in the infra-red region.

In this direction something has already been done in the cases of a very limited number of absorbing gases and the experimental results are in good agreement with predictions based on the simple extension of the ideas embodied in the quantum theory. It is very much to be desired that more experimental data in this field be secured with which to test this extension of the quantum theory. One result which is very encouraging has been obtained from a study of the absorption of HCl. The band in the neighborhood of the wave-length, 17,500 Ångström units, shows under high resolving power that the individual lines are double. This is what one should expect on theoretical grounds in the case of an element like chlorine, which is known from positive-ray analysis to possess the isotopes of atomic weight 35 and 37. Theoretically,

the doublet separation should be 13.54 Ångström units and the experimental value of the separations has been found by Imes to be 14 units with a probable error of one Ångström unit. This close agreement is not only a point in favor of the theory, but is interesting, because it suggests a possible experimental method of checking the results of positive-ray analysis in case the quantum theory of the structure of band spectra shall be found to stand the test of further experimentation.

It would not be fitting in this article to enter into details which are of their very nature extremely complicated. A résumé of the work in the field of infra-red band spectra up to the year 1923 and one which includes references to many of the important original papers was published by Randall in Volume lxii of the *Proceedings of the American Philosophical Society*. In this résumé Randall states: "It cannot be said that the problem of the molecular structure of simple molecules has been solved in the sense that the problems of the hydrogen atom and ionized helium have been solved. Rather the situation is more analogous to that of the heavier atoms where the solutions are qualitative rather than quantitative. The most definite results are the determinations of the moments of inertia from which it is possible in the case of the halogen hydrides to compute very accurately the distances separating the atoms."

It was stated at the beginning of this article that its object was to call attention to the results of seemingly permanent value in spectroscopy contributed by workers in the infra-red region of the spectrum. Even this brief and incomplete résumé will, it is hoped, interest some young physicists to experiment in a field which has been somewhat neglected of late years and which now offers greater promise of fruitfulness than ever before.

Test for Sugar in Soap.—GEORGE D. KING (*Chem. Analyst*, 1925, No. 43, 5) has adapted the Molish carbohydrate reaction for the detection of the presence of small amounts of sugar in soap. Ten grams of soap are completely dissolved in 150 c.c. of water. From 0.5 to 1.0 c.c. of this solution and 1 c.c. of a 20 per cent. solution of alpha naphthol in alcohol are mixed in a test-tube. Concentrated sulphuric acid is poured down the side of the test-tube and forms a layer at the bottom. If sugar be present, a distinct violet ring forms at the junction of two layers. J. S. H.

MODERN ORDNANCE.*

BY

MAJOR-GENERAL C. C. WILLIAMS.

United States War Department.

INTRODUCTION.

On February 26, 1920, I had the pleasure of presenting a paper before the Mechanical Engineering Section of The Franklin Institute on the "Types of Artillery Equipment Used by the American Expeditionary Forces in France, with a Brief Description of Their Uses and the Reasons for Their Adoption." It is the purpose of this paper to lay before you in a brief manner some of the developments which have taken place in ordnance matériel in the period which has elapsed since the World War.

The subject "Modern Ordnance" covers a very wide field, including weapons used by the soldier, such as rifles, machine guns, infantry guns and howitzers; all the different types of guns and howitzers used by the Divisional, Corps, and Army Artillery. It includes the special cannon such as railway and seacoast artillery, and anti-aircraft guns; ammunition, including bombs, fuses, propellants, explosives and projectiles for all the different types of cannon; tanks, tractors, and other special motor vehicles, and so on down the list of some one thousand items which are necessary for equipping the modern army. It will therefore be appreciated that in the time available, it will only be possible to invite your attention to a few of the more important phases of the problems of modern ordnance.

SMALL ARMS.

Semi-automatic Shoulder Arm.—One would not expect very much change in the Springfield rifle, which, as is well known, has been a very satisfactory weapon. We feel it is the best in the world. There is, however, an important development now in progress in the field of shoulder arms, which will have a very important effect on the arming of the infantry soldier. I refer

* Address delivered Friday, September 19, 1924, on the occasion of the celebration of the centenary of the founding of The Franklin Institute.

to the semi-automatic shoulder rifle. The importance of this new weapon will be appreciated when it is stated that the fire power of the soldier so equipped will be more than doubled.

FIG. 1.

Before the war the Ordnance Department constructed several models of semi-automatic shoulder rifle, but they were all of a very complicated nature, heavy and unreliable in their functioning.

FIG. 2.

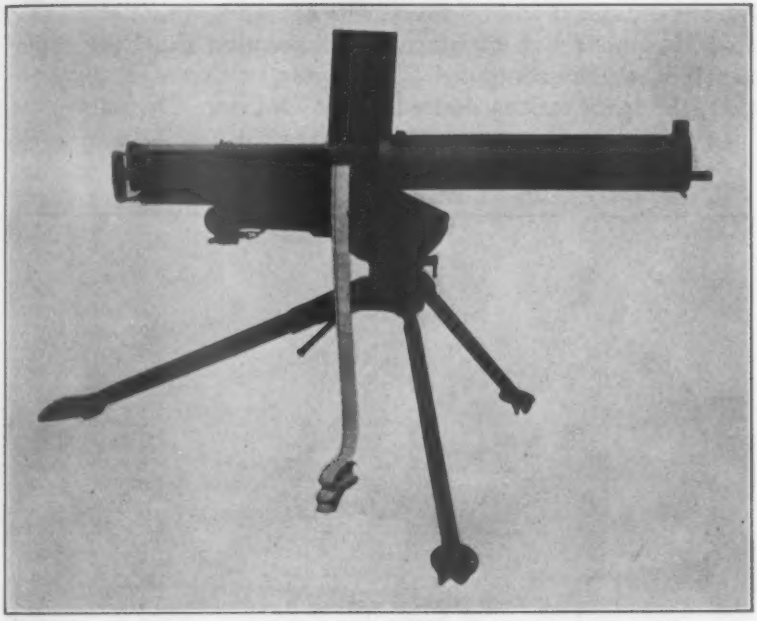
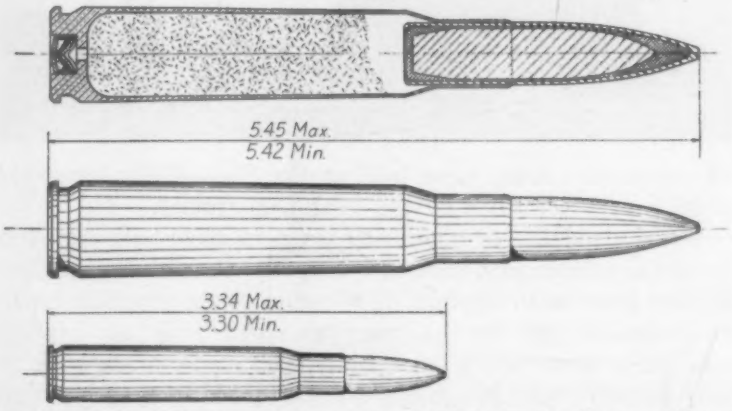


FIG. 3.

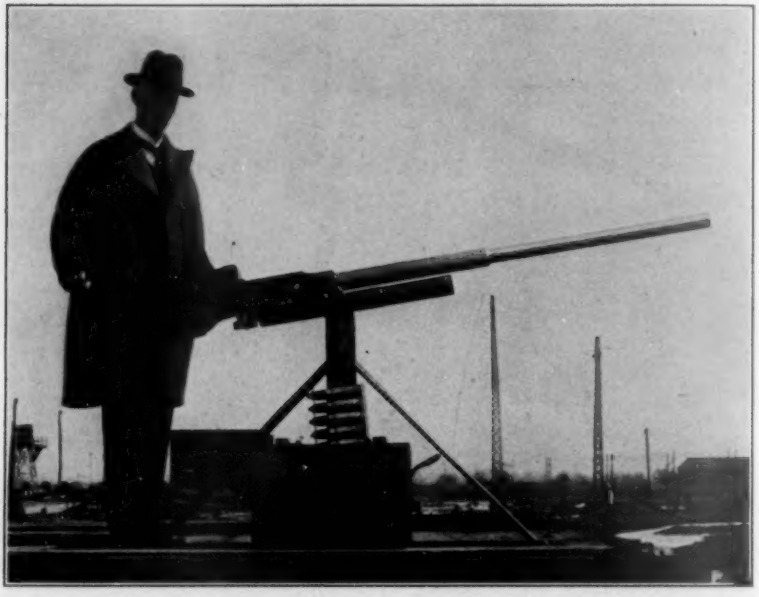


Ammunition for the calibre 50 machine gun, compared with that for the calibre 30 machine gun

It is very difficult to produce an entirely satisfactory shoulder arm to meet the rigid requirements of the military service, especially since the weight must be kept practically the same as that of the present magazine rifle.

During the World War, a great deal of work was done along this line. Several models were made operating on different principles, but none was satisfactory. Since that time, the experimental work has continued. Each year, with the exception of 1922, the specifications desired by the Ordnance Department for this type of weapon were sent to all interested American designers,

FIG. 4.



and competitive tests were held at the Springfield Armory by special boards convened by the War Department.

While a number of promising weapons have been tested and several have functioned quite satisfactorily, none has so far shown sufficient promise to warrant its adoption as the standard type of semi-automatic rifle for the American Army (Fig. 1). Judging from the progress which has already been made, we may be sure that American inventive genius will soon provide us with a highly developed and satisfactory semi-automatic shoulder arm.

Fifty-calibre Machine Gun.—The second important small arm development is that of the calibre 50 machine gun (Fig. 2). This weapon is available for aircraft and anti-aircraft use, with the possibility of future use in tanks, since its size permits us to use a

very effective armor-piercing bullet for anti-tank use (Fig. 3). Its rate of fire is about 550 shots per minute.

Thirty-seven Millimetre Automatic Gun.—The 37-mm. hand-operated gun firing a 1.25-lb. projectile was very successfully used

FIG. 5*a*.

World War type.

during the war by the Allies as an infantry weapon against machine guns, field fortifications and tanks, and also as an anti-aircraft weapon. The value of this gun would, of course, be greatly enhanced for aircraft and anti-aircraft purposes if it could be made to fire automatically. Several models of automatic aircraft cannon have been designed and built by private manufac-

FIG. 5*b*.

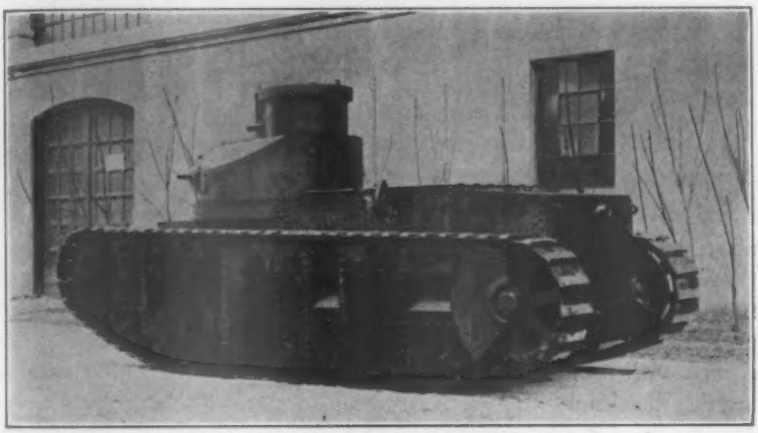
New type.

turers and by the Ordnance Department since the war. A very satisfactory 37-mm. full automatic aircraft gun has recently been completed by Mr. John Browning (Fig. 4). Tests held at our

proving ground with this type of weapon show that one direct hit with a projectile of this calibre fitted with a supersensitive fuse will cause the almost certain destruction of the airplane.

Our troops were equipped during the war with the Stokes Trench Mortar (Fig. 5*a*). This weapon became a very important one, due to the extensive trench warfare in France. It was capable of throwing three-inch high-explosive bombs short distances with great rapidity. The accuracy of the weapon was, however, poor and difficulty was encountered in placing the bombs in the nar-

FIG. 6.



row enemy trenches. To obtain satisfactory accuracy, the small infantry rifle cannon shown in Fig. 5*b* has been built. Actual firing tests with the new weapon indicate that it has satisfactory accuracy and more than twice the range of the war-type mortar.

TANKS.

The tank became so well known during the World War that it needs no special introduction or description. Suffice to say that the War Department has recognized the importance of this new weapon by the organization of special Tank Corps units for manning this matériel.

The war-time models of tanks do not have all the characteristics found necessary by post-war study of tanks.

In an effort to produce a more satisfactory tank, the Ordnance Department has built experimental models for test. Our models of light and heavy tanks are reasonably good.

The Tank, Model 1921 (Fig. 6), is in the medium weight class and is of sufficient size and weight to be an effective fighting machine. This is probably the most useful size of tank.

Some of the characteristics of this tank worthy of note are the high ends, which give good climbing ability, and the spring suspension of the running gear, which permits of a safe high speed of ten miles per hour. The armament is arranged in revolving turrets, allowing all-around fire.

The Tank Corps has operated and studied this tank and considers it as practically meeting the requirements for a fighting tank. However, we are very anxious to reduce its weight from twenty tons, as it now stands, to not more than eighteen tons. This problem is being actively attacked.

MOBILE ARTILLERY.

Divisional Artillery.—The close of the war found our armies equipped with the French 75, American 75 and the British 75, as the divisional guns, and the 155-mm. howitzer of French design as the divisional howitzer.

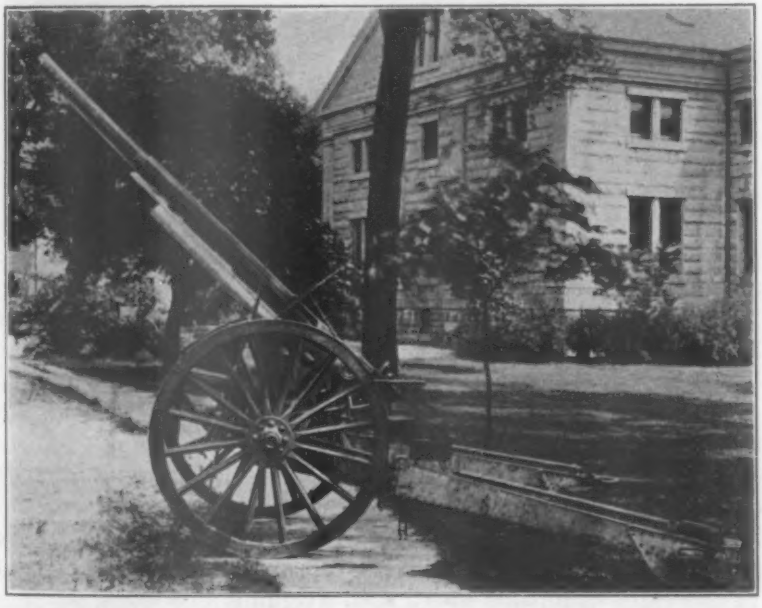
If we consider the French 75 gun (Fig. 7*a*) as representing one of the best types of divisional weapons used during the war, it will immediately be noted that this gun can only be elevated to 19 degrees with a corresponding range of 9700 yards, which means that the maximum efficiency of the gun can only be obtained by laboriously blocking up under the wheels of the carriage or by dropping the end of the trail into a pit. Even after doing this, it is found that the recuperator mechanism is not strong enough to return the gun to battery at high elevations, so that the rate of fire of the piece in this position is materially reduced. It will also be noted that this carriage has a very limited traverse, the maximum amount on each side of the normal being only 3 degrees. Limited traverse for a divisional weapon is a serious restriction in modern warfare, due to the new rapidly moving targets which are now encountered, such as tanks, motor vehicles, etc.

The new 75 divisional gun (Fig. 7*b*) permits the high angle of elevation of 45 degrees and the wide traverse of 40 degrees. Due to the great importance of the mobility of divisional weapons, which must accompany the division on the march, the artillery arm of the service has always, and for very good reasons, imposed

FIG. 7*a*.

World War type. 1897 gun. Calibre, 75 mm.; weight of projectile, 15 pounds; weight in firing position, 2657 pounds; maximum range, 9760 yards.

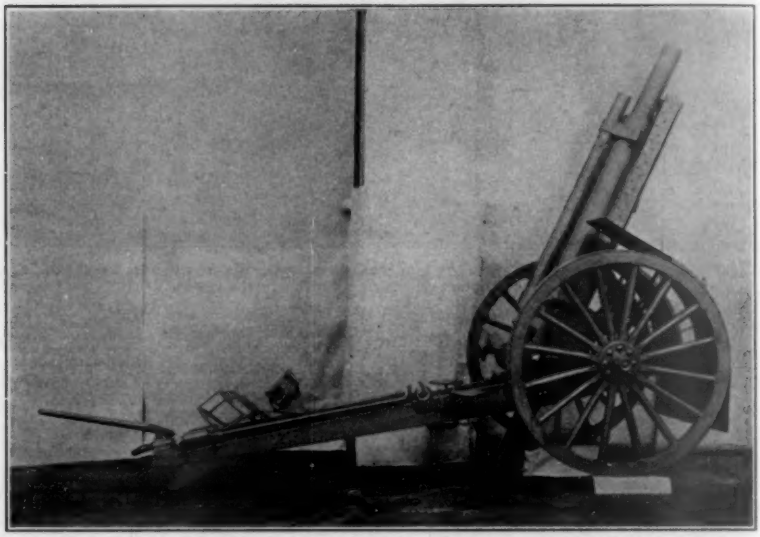
FIG. 7*b*.



New type. 1920 gun. Calibre, 75 mm.; weight of projectile, 15 pounds; weight in firing position, 2733 pounds; maximum range, 15,000 yards.

upon the Ordnance Department the conflicting requirements of greater range and lighter weapons. They very eagerly accept any increase in range, but jealously guard against any material increase in weight. In the post-war 75-mm. weapon the range of the gun has been increased to 15,000 yards, while the total weight of the unit has remained essentially the same. This has been accom-

FIG. 8.



New type. 1925 How. Calibre, 105 mm.; weight of projectile, 33 pounds; weight in firing position, 3200 pounds; elevation, 65 degrees; traverse, 8 degrees; maximum range, 12,000 yards.

plished by radical improvements in the design of the gun, carriage and ammunition.

Divisional Howitzer.—The 155-mm. Schneider howitzer was adopted in the emergency as the divisional howitzer, although it was known at the time that it was too heavy and lacked proper mobility. It was more properly a corps artillery weapon, for which it was also used during the last war.

The new 105-mm. howitzer (Fig. 8) is therefore not directly comparable with the 155-mm. weapon. The weight of this howitzer is about the same as the divisional gun, which means like mobility, while its great power is apparent from the range of 12,000 yards obtainable with a shell weighing 33 pounds, which is over twice the weight of the projectile used for the 75-mm. gun.

Corps Artillery.—The function of the divisional artillery just described is primarily the destruction of the enemy's soldiers. The function of the corps artillery is the destruction of the enemy's divisional artillery, for which guns of heavier calibres and longer ranges are necessary. Artillery of this type should have ranges sufficient to cover the front of an army corps and of

FIG. 9.

NEW TYPE
1921 GUN
Caliber ------- 4.7 In.
Wt. of Proj. ----- 50.5 Lb.
Wt. in Firing Position --- 11,800 Lb.
Max. Range --- 20,000 Yd.
WORLD WAR TYPE
1906 GUN
Caliber ------- 4.7 In.
Wt. of Proj. ----- 45 Lb.
Wt. in Firing Position --- 8,068 Lb.
Max. Range --- 14,000 Yd.

sufficient destructive effect for use as counter-battery weapons. For this material, the Department has endeavored to produce a gun which would have a range of about 20,000 yards with a projectile not over 60 pounds and a howitzer which should have a range of 16,000 yards with a projectile not over 100 pounds. It is found that the 4.7″ gun and the 155-mm. howitzer best meet these requirements.

The American 4.7″ gun, which was the one used during the

war as a corps artillery gun, has a maximum range of about 14,000 yards with a 45-lb. shell or about 12,000 yards with a 60-lb. shrapnel. The new 4.7″ gun, which has been built as a substitute for the war type, is much longer and a much more powerful weapon (Fig. 9).

The 4.7″ gun is logically mated with the 155-mm. howitzer

FIG. 10*a*.

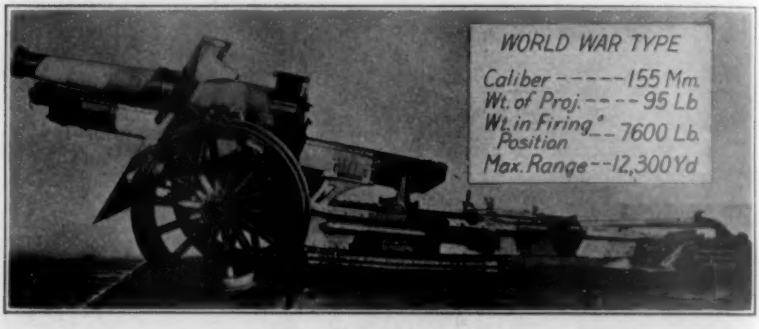
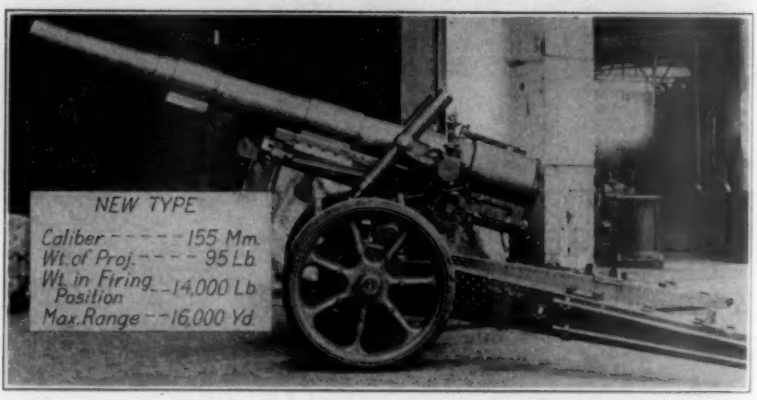


FIG. 10*b*.

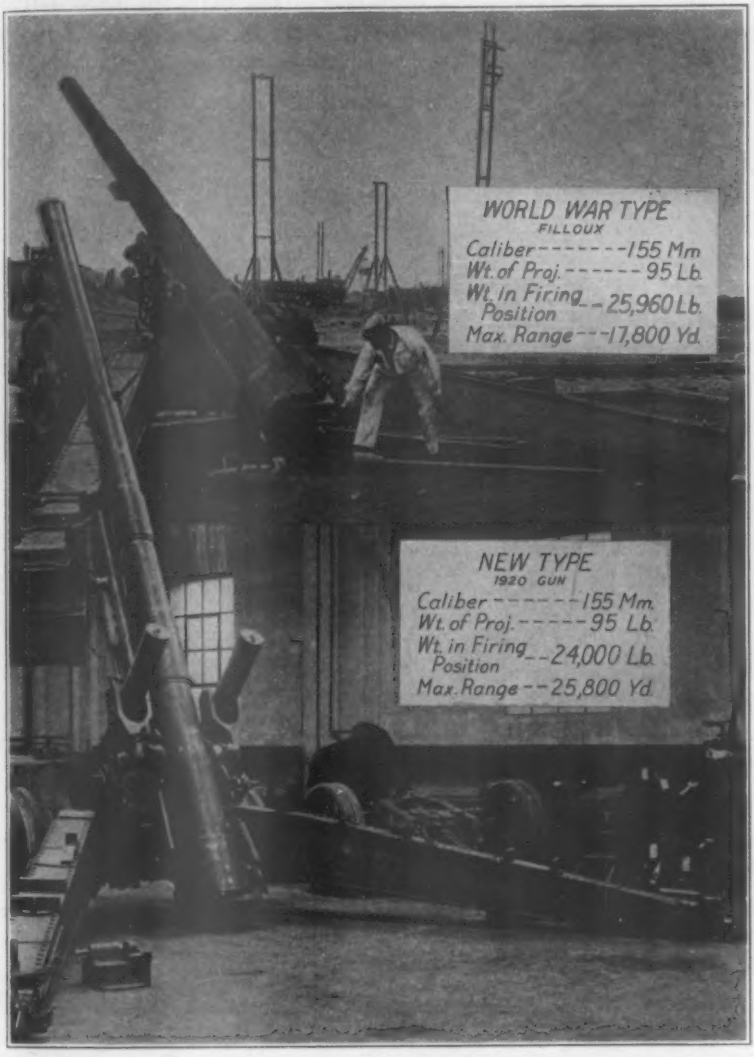


as these two weapons are roughly of the same mobility and power, the howitzer making up in size of projectile what it lacks in range.

The 155-mm. howitzer, war type (Fig. 10*a*), is of the Schneider design. This weapon, while a very excellent piece, has a maximum range of 12,300 yards with a 95-lb. projectile, while the new type which has been built as a substitute will give a range of 16,000 yards (Fig. 10*b*). The new 155-mm. howitzer, it will be noted, is quite similar in appearance to the 4.7″ gun.

The new carriage has a maximum elevation of 65 degrees and the very wide traverse of 60 degrees, as against 6 degrees obtainable

FIG. 11.


WORLD WAR TYPE
FILLOUX
Caliber - - - - - - - 155 Mm
Wt. of Proj. - - - - - - 95 Lb.
Wt. in Firing Position - - 25,960 Lb.
Max. Range - - - 17,800 Yd.
NEW TYPE
1920 GUN
Caliber - - - - - - 155 Mm.
Wt. of Proj. - - - - - 95 Lb.
Wt. in Firing Position - - 24,000 Lb.
Max. Range - - 25,800 Yd.

with the war-type carriage. It is interesting to note that the new 155-mm. howitzer can fire almost up to the range of the 155-mm. gun of war type, known as the G.P.F., which will be next

described under the heading of Army Artillery. While the range of the new howitzer approaches that of the 155-mm. gun of war design, its weight is less than half that of the 155-mm. gun G.P.F.

Army Artillery.—Guns of larger sizes than the ones which we have discussed are included in the army or general head-

FIG. 12.

quarters reserve artillery, and the first of this size is the 155-mm. gun.

This weapon is considered by all authorities as one of the best pieces of artillery brought out during the World War, and we have adopted its general characteristics in the design of our larger calibres. The G.P.F. gun has a range of 18,000 yards, but in our post-war gun we have obtained a range of 25,000 yards with a 95-lb. projectile (Fig. 11). The new 155-mm. gun is

capable of firing at an angle of elevation of 65 degrees which will permit its use against captive balloons, and it has a total traverse of 60 degrees, which is the same as the traverse of the G.P.F. It should also be especially noted that while this gun is very much more powerful than the G.P.F. of war design, we have been able to keep the total weight within the limits of the G.P.F.

The 8″ howitzer is the companion piece of the 155-mm. gun. This howitzer, with which our armies were equipped during the late war, was very serviceable, but was very much below the power desired in a howitzer of this calibre. The model shown has a range of 12,600 yards with a 200-lb. projectile, although most of the howitzers used during the war were of a still earlier model, and had a range of less than 11,000 yards. The new howitzer which will replace the 8″ war-type howitzer is mounted on the same carriage as the 155-mm. gun previously described. It has a range of about 18,000 yards, which is the requirement set up as a result of our war experience (Fig. 12).

TRACTORS.

At the outbreak of the World War, Germany was the only country well equipped with heavy artillery of the proper types. With the exception of the famous 75-mm. guns and the 155-mm. howitzers, the French armies were not well equipped with artillery, having practically no suitable heavy types. The British were also in the same state of unpreparedness. The close of the World War found all the Allies equipped with the heaviest types of artillery obtainable.

The extensive use of heavy guns accelerated the development of tractors for hauling this heavy equipment as a substitute for the horses which had been formerly used.

The Allies turned to the United States where the Caterpillar or track-laying type of tractor was in production for commercial and agricultural purposes, and some of these tractors were used for hauling guns at the front before the United States entered the war.

Since the war, the Ordnance Department has built several types of experimental tractors for the various artillery loads and has been testing, at its Proving Ground and in the field, commercial types of tractors suitable for military service.

It is the intention of the Ordnance Department to continue testing commercial tractors in order to always have available the necessary performance records upon which to base selections from the commercial field.

The study of commercial tractors has already resulted in

FIG. 13.

equipping one battery of field artillery with commercial tractors for field study.

As the commercial field has practically no production of very heavy tractors, the Ordnance Department will be required to carry on its own development of this type (Fig. 13).

ANTI-AIRCRAFT ARTILLERY.

The anti-aircraft artillery of the World War formed an important defence against aircraft. The efficacy of these guns was measured not so much by the actual numbers of aircraft destroyed, as by their effectiveness in preventing aviators from carrying out their mission of raiding, bombing and observation.

It is, however, a matter of record that the effectiveness of the allied anti-aircraft artillery measured in terms of shots fired per plane destroyed, increased threefold during the last year of the war. This rapid increase in efficiency was due to the development of guns, ammunition, fire control, and the training of personnel.

The effectiveness of anti-aircraft artillery can still be greatly increased by the construction of guns of higher muzzle velocities, better fuses, and improved fire control instruments.

FIG. 14.

New type. 1923 anti-aircraft gun. Calibre, 3 inches; weight of projectile, 15 pounds; total weight carriage and trailer, 11,750 pounds; elevation, 80 degrees; traverse, 360 degrees; maximum vertical range, 8400 yards; maximum horizontal range, 17,000 yards.

The 3″ anti-aircraft gun, Model of 1923E (Fig. 14), has just been completed and represents the best type of weapon produced up to this time. The gun, carriage and trailer are very light, so that the unit possesses excellent mobility. The gun, which has a

muzzle velocity of 2600 foot-seconds, is of higher power than the anti-aircraft guns in general use during the war period. Further radical improvements in our anti-aircraft artillery may be expected.

THE AMMUNITION PROBLEM.

In discussing artillery, one is apt to pass over the ammunition problem as relatively unimportant, yet it is the propellant in the round of ammunition which furnishes the motive power, and the projectile with its delicate fuse mechanism and bursting charge that produces the effect upon the enemy.

Each 75-mm. gun will during its accuracy life shoot more than sixty times the combined weight of the gun and carriage. Put in another way, out of the total estimated yearly steel requirement of the Ordnance Department in time of war, 6 million tons, 3¼ million tons are required for the manufacture of ammunition alone.

Some of the increase in the ranges obtained with the new types of artillery just discussed is due to improvements in the flight of projectiles achieved by perfecting the slope of the exterior of the projectile and by paying special attention to the balance of the shell.

In passing, it may be mentioned that in the field of propellants, smokeless powder has been manufactured for divisional artillery, which is flashless as well as smokeless. This powder when fired at night gives a dull glow at the muzzle instead of a blinding flash. The use of flashless powder renders the location of the firing battery by the enemy more difficult. The noise is also greatly reduced.

SUPER GUNS.

Railway Artillery.—The war hastened the use of guns and howitzers of large calibre mounted on railway carriages, and many different types were produced and used with great effect by both sides. Since then, the railway mount has been still further improved and special consideration has been given to the use of this type of artillery for seacoast defence purposes.

The 14″ gun railway mount, Model of 1920, is mobile in that it can be transported over the average railway lines, and its dimensions are such that it will pass through standard railway clearances. The unit can be fired either from the track, or, if

time permits, it can be lowered down and bolted to a concrete foundation.

It is equipped with its own power plant, which permits the

FIG. 15.

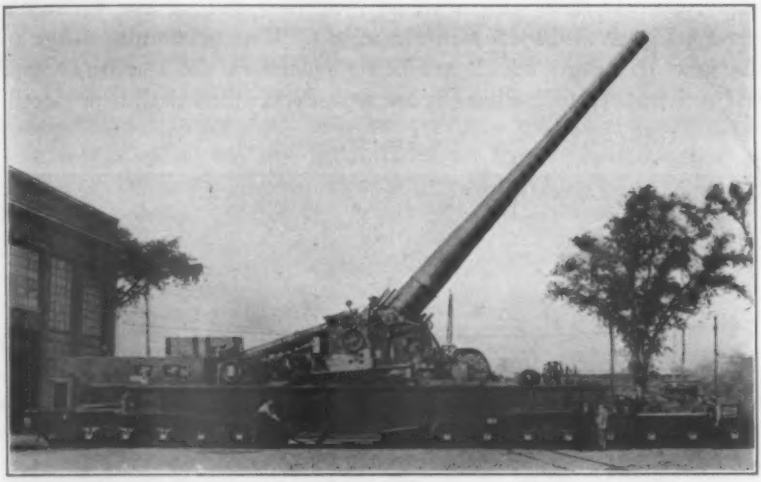


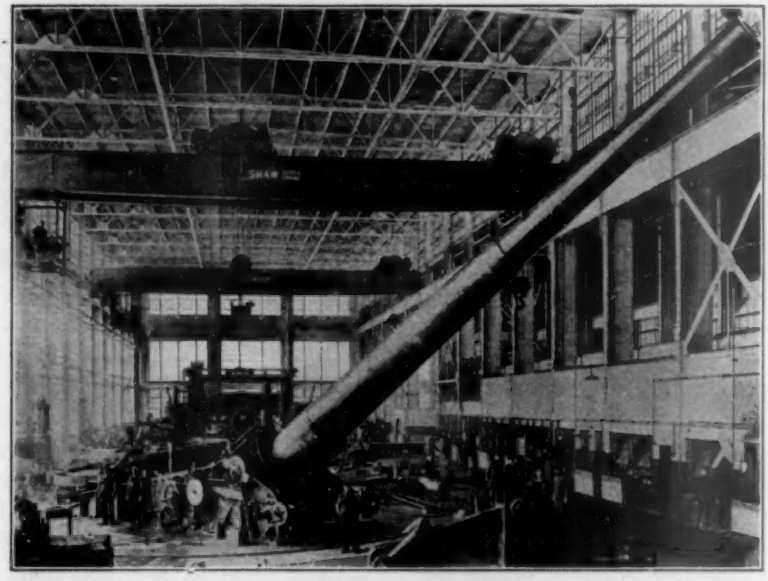
FIG. 16.

use of electric motors for elevating the gun, traversing the whole carriage, handling the ammunition, and for compressing the air

required for gas ejection. The range of this weapon is approximately 23 miles with a 1600-lb. projectile, and it can be fired at the rate of at least one shot per minute.

Seacoast Artillery.—In seacoast artillery, the principal improvements have also been in increased ranges due to higher powered guns and increased elevations. The maximum range of the new 16″ guns which are being placed in the Panama Canal and our important harbors is twenty-seven miles with a projectile

FIG. 17.



weighing over one ton. The new weapons are electrically operated, and although the weight of a complete round of ammunition is nearly 3000 pounds, the gun can be loaded, accurately aimed, and fired at a moving naval target once every 50 seconds.

GERMAN LONG-RANGE GUN.

Any discussion of large calibre heavy guns always brings to mind the German "Big Bertha" which alarmed the allied world by firing on Paris. At 7.15 on the morning of March 23, 1918, just two days after the Germans opened their offensive against the British Army before Amiens, people of Paris were startled by the loud explosion of something that had fallen on Quai de

Seine. Fifteen minutes later, there was another explosion of the same magnitude, but this time on the Rue Charles V. Fifteen minutes later, another explosion occurred in the Boulevard de Strasburg. This bombardment continued between March 23rd and August 9th, and during that time 183 shells fell within the walls of Paris and 120 shells fell outside, resulting in the death of 620 and the wounding of 356 citizens.

That this bombardment of Paris did not prove to be a factor of importance in the final outcome of the war is now appreciated. The moral effect on the inhabitants of Paris was to cause an exodus of a large number of the unemployed into the country. The laborers in munition factories and other war workers remained at their posts, and the flow of war matériel was not sensibly diminished.

It is now known that the guns used were 210 mm. in calibre or about 8″. Although it was agreed under the Armistice that these guns should be delivered to the Allies, they were promptly destroyed by the Germans, but from the information now at hand, it is known that they were high-powered guns of great length, using extremely high powder pressures. The projectiles, which weighed only 263 pounds, were too small for the task which had been assigned to them. The use of small calibre, extremely high-powered guns at exceptionally long ranges is of doubtful value and cannot be considered a profitable investment of funds or of manufacturing facilities. Recent tests have demonstrated that the aerial bomb is a much more effective weapon for such long-range bombardment. Experiments indicate that in the future the airplane will become a valuable adjunct to our long-range heavy artillery, and will quite possibly limit the development of the great calibre guns which would otherwise be constructed in the future to obtain ranges comparable with those of the German Bertha with projectiles of sufficient size to be effective.

BOMBING.

The Ordnance Department is charged with the design and production of aerial bombs and their supply to the Air Service. The opportunities for development in this line of ordnance have been great, and considerable progress has already been made. No bombs greater in weight than 660 pounds were dropped on either London or Paris during the war, and we now have bombs six times as large.

A great many different targets can be effectively attacked by this powerful new weapon of warfare. Munition plants, ammunition dumps, railway bridges, storehouses and naval vessels are some of these. Heretofore such targets have been attacked by artillery when they were within range; however, the range of

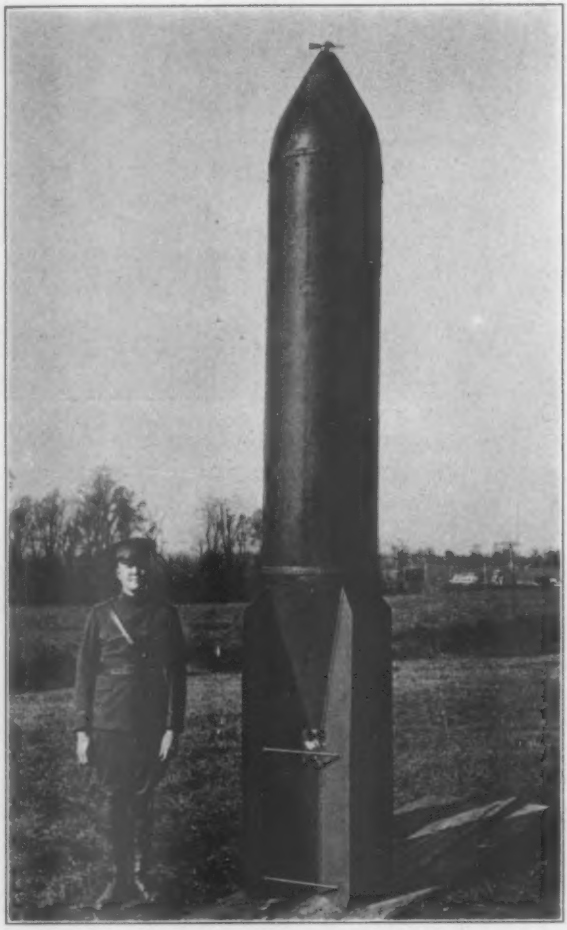
FIG. 18.

The detonation of a 600-pound bomb. The effect produced indicates the power of this bomb.

guns is limited, and through the airplane and the bomb, these targets can be reached 100 miles or more beyond the theatre of actual conflict. With the great variety of targets opened to attack, there have been developed the various classes of bombs, each designed to produce the greatest destruction against a certain group of targets. Of these bombs, the demolition class is the most important. They are designed to destroy targets typified by the average factory building. They are made in different weights

from 100 pounds to 4000 pounds. The only limit to large bombs of this type, is that which aircraft can carry. It is

FIG. 19.



The world's largest bomb. A 4000-pound demolition bomb, which carries nearly a ton of high explosive.

believed that the largest size needed at present does not exceed the 2000-lb. bomb.

Experiments are in progress with a 4000-lb. bomb to determine whether one of this size is required. This bomb is probably

FIG. 20a.

FIG. 20b.

Test structure after detonation of 100-pound demolition bomb. This bomb was placed in the centre of the front room on the first floor of the house and fired statically to simulate a direct hit with delay action fuse.

larger than any produced by any other country. The fact that it will excavate a crater 57 feet in diameter by 19 feet deep in average ground is an indication of its power. Such a bomb might

be used against a capital ship, against a large manufacturing plant, or in bombing an extensive railroad terminal.

Approximately 50 per cent. of the bomb by weight is high explosive. Its capacity for explosive is very large when compared with that of the artillery projectile which carries only 2 to 15 per cent. by weight. When a high explosive charge is

FIG. 21.

The ex-German battleship *Ostfriesland* hit by a 1100-pound demolition bomb in the test held off the Virginia Capes, July, 1921.

detonated, a blast is produced and the destructive effect increases with the amount of explosive in the charge. The design of most buildings and other material targets is such that they are very susceptible to destruction by blast, therefore a demolition bomb carrying a large amount of explosive is a very effective agent against such targets, and for this reason, the bomb is more effective than the projectile of the same weight.

The average factory is most effectively destroyed when a direct hit is made, although if a bomb of sufficient size hits near

a building, it will produce very material damage. In the case of a direct hit in order to get the full effect of the blast produced, detonation must be delayed until the bomb has passed through the roof and floors of the building and reached the ground floor or basement. The blast then literally bursts the building, throwing the roof off and demolishing the walls. That demolition bombs can be effectively used in the attack of naval vessels has been demonstrated in the experiments which have been conducted quite recently. An armored ship is more easily damaged by a near hit than by a direct hit. Using a fuse with a slight delay, the bomb can be made to penetrate 40 to 60 feet below the surface of the water before functioning. The water then acts to transmit the terrific shock of the detonation to the unprotected hull of the ship.

The bombing of the ex-German battleship *Ostfriesland* took place off the Virginia capes during the month of July, 1921. A 2000-lb. bomb striking close to this battleship caused it to sink very rapidly.

As a branch of modern ordnance, no subject is receiving more careful attention than the production of bombs.

Industrial Mobilization.—It is hoped that the preceding résumé will have given you some idea of the rapid developments which have taken place in ordnance matériel since the World War. These developments were greatly stimulated by the help given during the latter part of the war by the scientists and engineers of the country, who were able to devote a great deal of time to this work. In time of peace these improvements will continue, although at a slower rate, so that over a period of a number of years, there will be many radical changes in the weapons of modern warfare. These considerations make it uneconomical to maintain a large stock of war matériel on hand. It should be understood, however, that a reasonable reserve of war matériel is an absolute necessity, as otherwise the armies, in the case of an emergency, could not be armed for many months after the declaration of war. A carefully balanced reserve of the best ordnance matériel obtainable must therefore be kept, in order to equip and supply troops until new matériel can be obtained from new production.

It was clearly demonstrated during the World War that man power could be much more quickly raised and trained than the armies could be equipped with the proper ordnance matériel. The

mobilization of industry was found to be just as important a factor as the mobilization of man power.

Modern ordnance is used in such vast quantities by modern armies that a war requires a complete mobilization of the entire industry of the country. Ordnance is difficult to manufacture, being in general more difficult of fabrication than most commercial articles. Peace-time industrial preparedness measures are as important to the safety of the nation as the peace-time preparation of armies.

The industrial war plans, to which the Ordnance Department has devoted a great deal of its effort since the war, will, I feel sure, form fully as important a factor as the development of ordnance matériel. Both should be advanced together, and neither should be neglected.

Permit me to outline in the briefest possible way what the industrial war planning of the Ordnance Department contemplates. Starting with the organization tables, mobilization plans of the War Department and tables of basic allowances, the requirements of each article of ordnance, of which there are some 1200, have been computed. These requirements include not only the quantities of ordnance required for initial equipment of the armies, but also cover replacements, wastages, quantities required for training, etc., based upon data compiled from the experience of the last war. Complete drawings and specifications for all of these items have been or are being completed. There is also available a large mass of manufacturing data including route sheets, shop layouts, cost data, etc., pertaining to the manufacture of many of these items. In many cases, complete sets of manufacturing jigs and fixtures are available as are also sets of manufacturing and inspection gages.

In line with its war experiences, the Ordnance Department has divided the country into fourteen ordnance districts. This division was based upon the location of facilities for ordnance production. In each district, a well-known and successful business man has been appointed district chief, who will have entire control and responsibility for the procurement of the ordnance matériel allocated him for production in his district, under the direct general supervision of the Ordnance Office. Actual orders to be carried out in time of war have already been allocated to the various districts. The district chiefs have made surveys

of the principal manufacturing plants in their districts, with special reference to their facilities and organization for the manufacture of ordnance matériel. In many cases, orders have been placed with manufacturing plants by district chiefs to become effective in case of an emergency. It is intended eventually to have orders placed for the purchase of all ordnance required, based upon computed requirements. The larger manufacturing companies of the country have responded to this industrial preparedness movement in a patriotic manner, and are coöperating with the Ordnance Department to the fullest extent.

The perfection of this industrial preparedness program with the full coöperation of industry will make it possible to rapidly equip our troops with modern ordnance should another emergency arise.

CONCLUSION.

In conclusion, it may be stated that while man power, other things being equal, remains and always will remain the deciding factor in war, the tremendous growth in quantity and complexity in the special instruments of war renders their supply the limiting factor in the development of the military effort of our nation and in making our man power effective.

The weapons used by men are but tools, and nations armed with inferior weapons may be hopelessly handicapped. A preponderance of numbers may make up for the inferiority if it is not too great. Our duty is not to prepare for war as a game in which the uncertainty of victory will add interest and zest to the conflict. It is to insure that, if war unfortunately comes, the United States will be able to make the most effective use of her resources with the object of securing a successful peace as quickly as practicable.

Hydrogen Sulphide Literature.—C. W. MITCHELL and S. J. DAVENPORT (Public Health Reports, 1924, xxxix, 1–13) have made a study of the literature on the physiological action of hydrogen sulphide. While this gas was known to the ancients, apparently the first recorded deaths due to its action occurred during the last quarter of the eighteenth century in France. The first recorded cases of poisoning by hydrogen sulphide in the United States were reported in 1851. It is an extremely toxic gas, and may occur as an industrial poison. It will produce toxic symptoms in a concentration of 0.005 per cent. The exact mechanism of the poisoning is unknown. A bibliography of more than eighty references is appended. J. S. H.

LOW-TEMPERATURE COAL CARBONIZATION AND ITS PROSPECTIVE INDUSTRIAL DEVELOPMENT.*

BY

HORACE C. PORTER, Ph.D.

Member of the Institute.

In America the fuel question affords the average citizen very little concern, except in times when there is difficulty, through strikes or other industrial disturbances, in putting an adequate supply in his bins, or when the price at times rises to a disproportionate figure in relation to other costs of living.

The fundamental position of fuel in civilization, as the prime mover in all industry, the heat supply agent supreme, utterly indispensable to the manufacture and transport of the world's goods, is not as thoroughly and widely appreciated as it should be. If it were, we would have a more general effort to use methods of increased economy in fuel application, and a livelier interest among the whole people in how best to use coal with regard to scientific principles.

It must be recognized, however, that in recent years power plant economies have markedly increased, central station development has been rapid, powdered fuel has come into its own, and by-product coking and use of the by-product gas has largely displaced the old wasteful coking methods—all of this with evident beneficial influence on the consumption of fuel per unit of industrial product, in goods or energy.

The U. S. Geological Survey reports the consumption of fuel in all plants furnishing electricity for public use, for the years 1919 to 1923, as follows:

Year.	Output by the Use of Fuel. (Kilowatt-hours).	Consumption of Coal and Its Equivalent in Other Fuels.		
		Net Tons.	Lbs. per KW-hour.	Per Cent. of 1919 Rate.
1919	24,176,000,000	38,880,000	3.2	100
1920	27,248,000,000	41,420,000	3.0	94
1921	25,863,000,000	35,240,000	2.7	84
1922	30,240,000,000	38,000,000	2.5	78
1923	36,092,000,000	43,522,000	2.4	75

* Presented at the stated meeting of the Institute, held Wednesday, December 17, 1924.

There has been a decrease therefore of 25 per cent. in five years in the amount of fuel required per unit of energy output.

Among these economies, these advances toward more rational use of fuel, where does carbonization take its place? Why do we carbonize coal, and by what methods in general is it to be done most advantageously?

So far, in America, there has been little, if any, effort to apply directly the carbonization of coal to mitigation of the smoke evil. We have been carbonizing coal almost exclusively for the production of metallurgical coke and city gas, special fuels not applied directly to relieve the smoke nuisance. Yet smoke damage is admittedly serious, a large item of everyday living expense, a hindrance to civic progress, and it may be abated materially by increased practice of coal carbonization.

The Mellon Institute, of Pittsburgh, by direct measurements over a period of twelve years, has found for 1923–24, in Pittsburgh a rate of deposit of insoluble solids from the air of *3.9 tons per average square mile per average day.* There has been a marked decrease during twelve years in the amount of tar in this deposit, indicating some decrease of dense smoke, but a large increase of combustible solids other than tar has occurred, which indicates that half-burned coal, soot and cinders are more than ever being scattered abroad from raw-coal furnaces—by the increased drafts now commonly resorted to.[1]

With anthracite and coke fires and increased use of gas in industrial and domestic heating, smoke and cinders may be greatly reduced. The large central station is, in modern practice, usually so designed as to be able to burn bituminous coal without smoke, but the smaller industrial and the domestic plants are the ones where a smokeless fuel is much to be desired.

The carbonization of bituminous coal, therefore, may well be expanded in the direction of supplying a general fuel of smokeless character, whether it be coke or gas or both, for the saving of labor, saving of the rational values in the coal, and saving of the damage-cost from smoke and dust.

The costs here offer an obstacle. Industry has been slow to expand coal carbonization into this field, because the balancing of costs by the revenues attainable is a precarious business. We carbonize, in America, now, in round numbers, 80,000,000 tons

[1] H. B. Meller, *Jour. Ind. Eng. Chem.*, 16 (1924), 1049–51.

of coal per year, about one-seventh of the total coal used. But 90 per cent. of it is for purposes other than the supply of a general industrial and domestic fuel. Certain specialized markets, as in metallurgy and in the smaller field of city gas supply, pay the prices required for carbonization products, but, on the other hand, for general fuel purposes the expense of the process holds back its expansion.

It is of interest to note the items of this expense and of the possible returns, both for the prevailing high-temperature processes, and the still embryonic, so-called low-temperature carbonization processes. Any figures chosen for the latter must be largely in the nature of guesses, since there is as yet in this field no such thing as established yields and markets.

Low-temperature carbonization of coal is struggling to get upon its feet industrially and commercially. If it can keep its costs of operation and investment within those of the older methods and can find special markets for its high yield of oils, such as for creosoting of wood, for example, its returns may prove to be such as to offer an inducement to capital investment. It must be recognized, however, that the process is in the development stage, and, while showing promise, is not yet ready for widespread commercial adoption.

The costs include those of the plant investment, the labor and materials for operation, and the losses of material incident to the process. From coal worth one-fourth cent per pound we must get marketable products having an average value of nearly one-half cent per pound in order to pay the costs and clear a reasonable profit for the enterprise. Although gaseous fuel, made by coal carbonization, on account of its convenience and suitability for special uses, commands a price of fully 1.0 cent per pound, oils and motor fuel an average of but little less than 1.0 cent, and coke perhaps 0.3 cent (only a little more than the coal from which it is made), still the coke constitutes by weight three-fourths of the total of products, and accordingly the attaining of the needed one-half cent average is not a simple problem.

To improve the situation and induce more rapid commercial expansion of carbonization into the general fuel field, it is necessary to direct efforts, as is being done, toward two main objects: First, to reduce the investment and operating costs per unit of output (partly through increase of capacity or producing rate), at

the same time, reducing losses such as consumption of coke or gas in heating the retorts; secondly, to improve the yields and develop markets for the products.

Commercial coal carbonization in this country has been, up to this time, almost entirely by the high-temperature method, making hard coke, a relatively high yield of gas, and a degraded tar, polluted with carbon and pitchy hydrocarbon residues. Low-temperature carbonization (that is, with retort walls not over

TABLE I.

Costs and Returns in Coal Carbonization.

(Per Pound of Coal.)

	(I) High-temperature Processes.		(II) Low-temperature Processes.		(III) Ideal Combination Process.*	
Costs:						
Coal @ $5.00 per ton.....		.250¢		.250¢		.250¢
Conversion expense, fixed charges, etc.....		(see below)		(see below)		(see below)
Returns:						
Coke @ $6.00 per ton.....	.174		.204		.180	
Gas @ 5¢ per 100,000 B. t. u.	.165		.090		.155	
Tar and oils @ 5¢ and 6¢ per gallon.....	.030		.072		.060	
Motor fuel @ 20¢.....	.026		.026		.030	
Ammonia @ 3¢ per pound sulphate.....	.038		.012		.027	
		.433		.404		.452
Balance available for conversion costs, fixed charges and profit.....		.183¢		.154¢		.202¢

*Under this heading (III) are given results of an ideal process, not yet realized in practice, but believed possible on theoretical grounds, namely, a process which will withdraw *all* of the volatile matter from coal at moderate temperatures, and yet not crack destructively the valuable oils and vapors.

1470° F.), securing less gas, a quicker-burning coke, and a large yield of thinner, less-degraded oils, is striving to perfect its processes and produce a more valuable group of products than by older methods.

As shown in Table I, it does not appear that the new method will do this until a higher-priced market for its coke and oils is established or until it improves its yields, especially of gas, by better application of scientific principles of carbonization.

Rather than leave 10 per cent. of volatile matter in the coke, where its value is 0.3 cent per pound, it appears rational commercially to try to drive it out as gas where it may be worth three-fourths cent to 1.0 cent per pound. If this can be done practically without detracting from the utility value of the coke, and at temperatures sufficiently low not to crack disadvantageously the valuable oils, the net returns of low-temperature carbonization should show an improvement.

This object is sought in coking methods such as Wallace's, and in recent patents of A. W. Warner and the Economic Carbonization Co., which latter proposes to move coal upward in a retort through gradually increasing temperatures, withdrawing the gases and vapors *away from* the source of heat, that is, in this case, toward the centre of the retort and then downward. In this way the direction of flow of gases and water vapor and oils is into the cooler sections of the coal charge, and there may be used in the outer sections a high enough temperature to devolatilize the coke at a practical rate, without any undesirable cracking of the oils and gases.

The mechanism of coal carbonization has been graphically depicted by a number of writers. Under high-temperature conditions, as in coke ovens, the diagram in Fig. 1 shows how a gradually contracting plastic layer of softened coal recedes from the heated walls toward the centre of the oven.

Since this layer is viscous and permeable with great difficulty, the volatilized products pass out very largely through the coke, that is, *toward* the hotter sections. In this, the more common method of carbonization, therefore, the primary volatile products, instead of being driven ahead of the heat, pass back toward it; the mixture of water vapor, heavy hydrocarbon vapors (probably of complex ring and side-chain structure), hydroxyl bodies like phenols in important quantity, and various permanent gases, all in a conglomeration of constantly changing proportions, is reduced to a state of degradation that is dependent chiefly on the degree of temperature at the heat source.

This is unfortunate, since, to get practical economy in speed of coking, in a stationary charge of this kind, the heat source temperature must be high, and the cracking of oils and gases produces much carbon, anthracene, naphthalene, phenanthrene and similar undesirable pitch-forming materials.

Low-temperature carbonization has been brought forward chiefly with a view to the lessening of this undesirable cracking and the preservation of the oils and rich hydrocarbon gases in less degraded form. Many mechanical expedients have been tried for getting the heat into and through the charge at a suitable speed, but it has been difficult with the flow of gases counter to

FIG. 1.

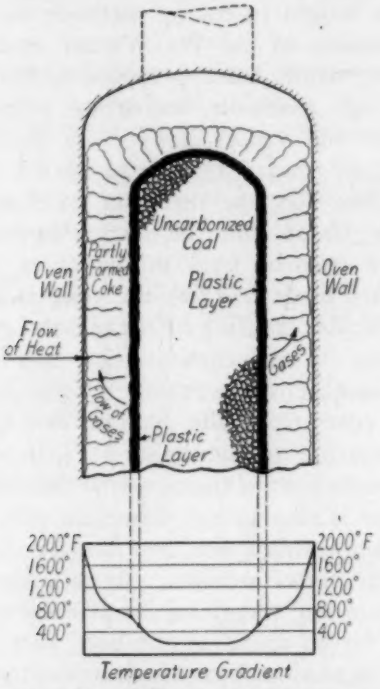


Diagram illustrating formation of the plastic ring and progress of carbonization in the high-temperature methods, such as the by-product coke oven.

that of the heat and the need therefore of maintaining very low temperatures.

Yields of 20 to 25 gallons of oil per ton of coal, as compared with 10 to 12 by high-temperature methods, and gas of 800 to 950 B.t.u. per cubic foot as against 530 to 580, are readily attained. The coke usually is made with 5 to 17 per cent. of volatile matter retained, giving it a quality of ready ignition, and a high heating value per pound.

In Table I, an attempt is made to put a market value on these yields and qualities. Low-temperature coke is placed at the same value per pound as the high-temperature product, but it gains by its higher net yield (68 per cent. as against 58 per cent., after deducting what is necessary to devote to heating of the retorts). Its gas yield, in spite of its superior quality, is so low in quantity that on a total B.t.u. yield basis it does not reach ordinarily 60 per cent. of the high-temperature carbonization yield.

All in all, the summary (Table I) shows that, unless the oils can find a high-priced market, or unless new developments are successful in producing *both* a good gas yield and a high yield of oils, the returns from low-temperature carbonizing do not offer encouraging prospect of surpassing those from accepted high-temperature methods. There appears to be encouraging prospect that low-temperature tars may find remunerative market for wood preservation, owing to their high toxic value, large content of high-boiling tar acids, and penetrating power.[2]

If a cheaper grade of coal is used as a raw material—a coal not suited for the high-grade market demands nor for coke-oven use—the commercial prospect becomes better, and there are many such coals available in the shape of screenings (especially in Mid-west fields, where they amount in some sections to 40 to 45 per cent. of the mine product)—also poorly coking coals, and lignitic coals. The returns, in such case, are but little reduced, and the raw material cost is much lower.

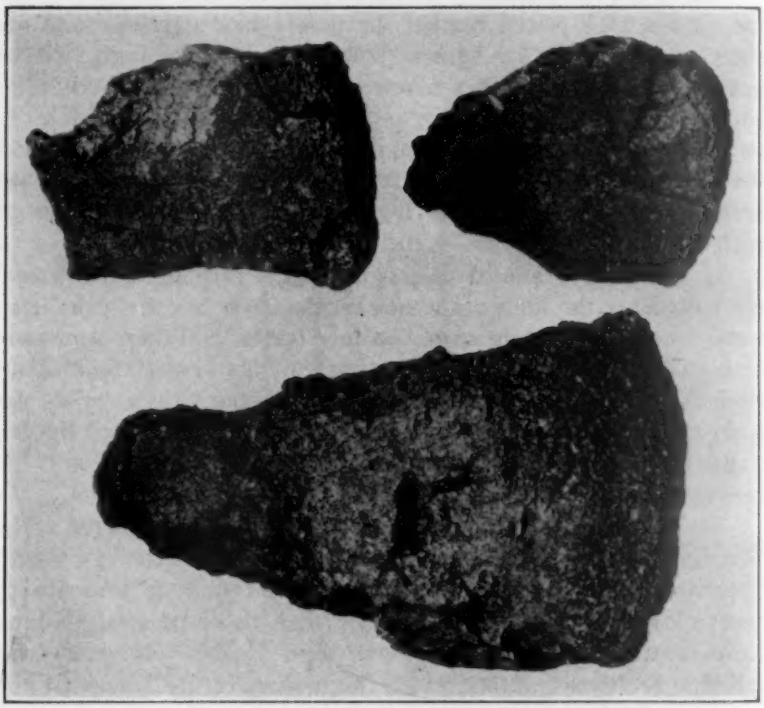
The ideal coking process, itemized in column III of the table, is conceived as one which will give a devolatilized coke of firm structure and good burning qualities, not requiring briquetting, gas yields accordingly much greater than those of straight low-temperature processes, and oils in high yields. Its retort will combine sections for moderately high-temperature stages of the process, with lower temperature sections where the primary volatiles are drawn off away from the heat. Much of the lighter oils will thus be preserved, and the heavy oils will be condensed in the coal, to be carried with it into the higher temperature sections and form coke and gas. Practical working difficulties may be encountered with such a process, but it is something to strive for, and will secure the maximum of values from the coal.

[2] "Low-temperature Tars and Wood Preservation," R. P. Soule, *Proc. Amer. Wood Preservers' Assoc.*, 1922, 114–127.

The processes that are under trial in this country (not including "complete gasification" processes) provide, essentially all of them, for movement or agitation of the coal in the retort.

Prof. S. W. Parr's experiments at the University of Illinois have not so far used agitation in the final stage of coking and his coke, partly for that reason, is of excellent quality. His is a two-stage process wherein the coal first is turned over in a revolving

FIG. 2.



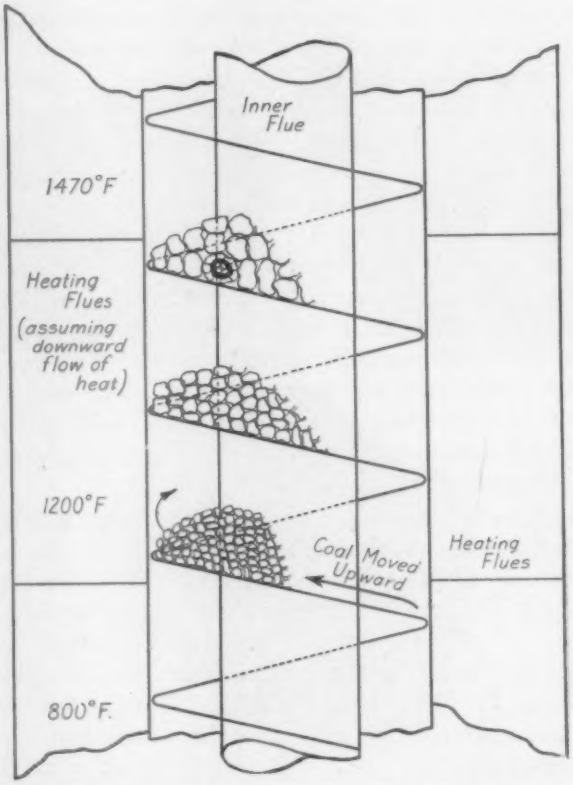
Low-temperature coke, made by Parr's process from Illinois coal (Saline county), about one-half actual size. (The two smaller pieces have been sectioned.)

drum heater, bringing it to a temperature of 450° to 550° F. (just short of fusion), when it is transferred quickly to a vertical metal retort, heated from outside to about 1300° F. and the coking therein completed. The volatile matter in this coke runs about 4 to 5 per cent. Typical pieces and sections are shown in Fig. 2.

With the Illinois type of coal, of 8 to 12 per cent. water and 15

to 18 per cent. oxygen, the preliminary heating in Parr's method takes care of a very large proportion of the total heat input necessary for coking—more than 50 per cent. in fact—and the second stage in this process proceeds very much more rapidly than in other low-temperature processes. The coke is remarkably strong

FIG. 3.



Diagrammatic illustration of the worm-conveyor type of low-temperature carbonizing retort (not illustrating any particular commercial process).

and of excellent quality, containing from 4 to 7 per cent. volatile matter, according to the temperature used.

A number of processes, such as the Greene-Laucks in America and the Marshall-Easton in England, have used the worm-conveyor principle for movement of the coal through the retort. Fig. 3 illustrates, merely in diagrammatic form, the method used

in such processes, when the retort is vertically placed. The movement is assumed to be upward, and the temperature of the heating flues graded from higher at the top to lower at the bottom. The shaft of the worm may be utilized either as an auxiliary heating flue, or as an offtake for the gas and by-products. With such method of movement of the coal on a conveyor, there may be but little mechanical interference with the agglomeration of the caking mass, and in fact, small-sized coal or screenings may build up into marketable sizes of lump coke or semi-coke.

The Greene-Laucks process, developed first in Denver, Colo., is now being tried out with Illinois coal screenings by a large coal-mining company in that state. This process propels the coal upward on a worm conveyor in a vertical retort in which heat is applied both on the outside and within the hollow conveyor shaft. As the object, in this case, is to make a good solid fuel with recovery of tar oils, little attention is paid to gas yield, and 15 to 17 per cent. of volatile matter is left in the coke. The retorts now operating with this process have been producing good strong semi-coke over long-continued periods, at a rate of twenty-four tons of coal carbonized per retort per day. The fuel is readily ignited, burns smokelessly and holds the fire well, as the writer has personally demonstrated by trial. In Fig. 4 are shown typical pieces of this coke, some of them sectioned.

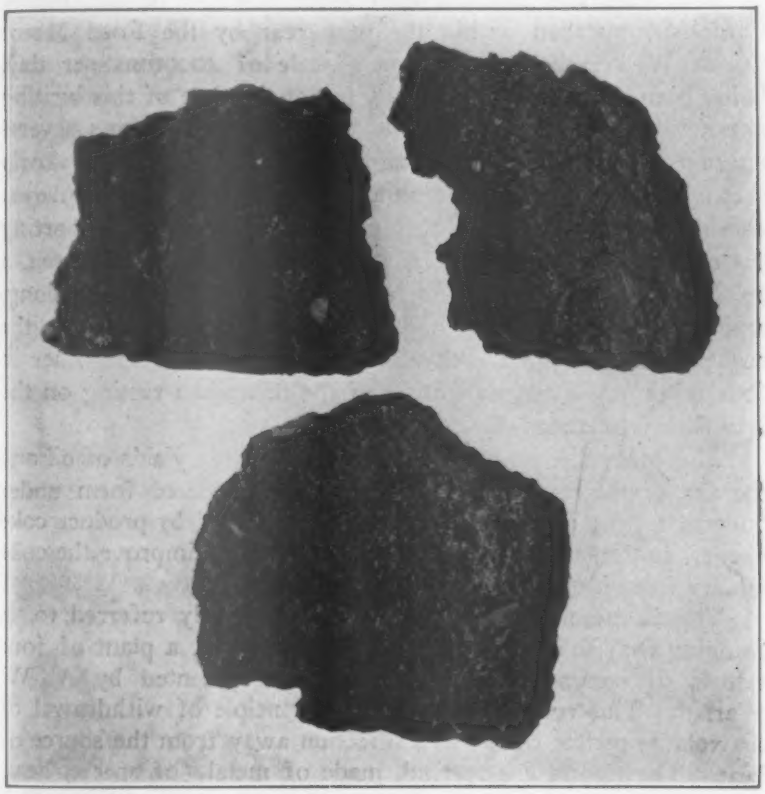
The Carbo-coal process is probably the most widely known American low-temperature carbonizing process. It has been operated commercially within the last few years on a large scale at Clinchfield, Va. At present this plant is idle, pending further development of the apparatus. Experimental work upon the process is being done by the Consolidation Coal Products Co., at Fairmont, W. Va., where C. V. McIntire has designed, patented and operated for some months a modified Carbo-coal primary retort.

The process (as operated at Clinchfield) used three stages, carbonizing at low temperatures in primary retorts, briquetting of the primary carbonized residue with pitch binder, and hardening or devolatilizing of these briquettes in high-temperature retorts.

Mr. McIntire has furnished to the writer samples of his semi-coke and tar, and the following information about his new retort. As most recently developed, it is a single shaft, horizontal retort,

metal-lined, wherein the coal, continuously fed, is stirred with an agitator of special design. With a length of setting of sixteen feet, this retort has, during long periods, handled fifty tons per day of Pittsburgh seam coal, giving average time of contact of coal with heating surface of one-half to three-fourths minute. With

FIG. 4.



Low-temperature coke, or semi-coke, made by the Greene-Laucks process, on a commercial scale, from Illinois coal screenings; about one-half actual size. (Two pieces shown in section.)

the retort shell at 1100°–1200° F., the temperature of coal and semi-coke was 700°–800° F., semi-coke was obtained of 12–14 per cent. volatile matter, gas of 875 B.t.u. per cu. ft. amounting to 2500 to 3500 cu. ft. per ton of coal, and tar oils, 23 to 30 gallons per ton, of a specific gravity of 1.080 and of which 70–80 per cent. could be distilled down to pitch coke.

This process differs from those using conveyors for the coal, in that it tumbles or agitates the coal by means of vanes or paddles, in order to secure quick heating of all sections of the charring mass. The semi-coke accordingly is not lumpy, but granular, and showing a pellet formation such that only about 20 per cent. can be used for domestic fuel without briquetting.

A process that has attracted much attention is the Piron-Caracristi, installed within the past year by the Ford Motor Co. at Walkerville, Ontario, on a scale of 400 tons per day. It has been operated intermittently but at the time of this writing is not yet on a commercial basis. The process presents several unusual features. Coal in a one-half inch layer is moved slowly through a distilling chamber, on a horizontal metal plate conveyor to which heat is transmitted through a molten lead bath supporting the conveyor. The coal layer, although thin, is of large area, a belt nine feet wide travelling in a chamber forty-five feet long, and the capacity may be as high as four to five tons per hour, the coal passing through the chamber from one end to the other in four minutes. The temperature of the belt when resting on the lead bath is at 1200° F.

This process is planned for recovery of large yields of oil and the use of the fine char for blowing in powdered form under boilers and for mixing with the coal charge of by-product coke ovens. In the latter application it is designed to improve the coke quality from high-volatile coals.

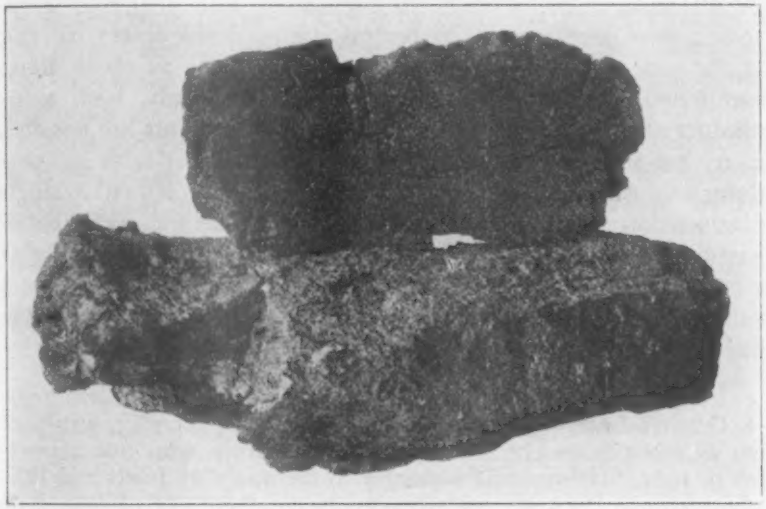
The Economic Carbonization Co., previously referred to, is bringing near to completion at Petersburg, Va., a plant of four retorts of commercial size designed and patented by A. W. Warner. This retort will utilize the principle of withdrawal of the volatile matter chiefly in a direction away from the source of heat. The retorts are vertical, made of metal (of special heat-resisting alloy in the top section), and are heated in a setting of gas-burning flues. These flues provide higher heat at the top of the retorts, lower at the bottom. Within each retort is a worm conveyor propelling the coal upward; through the hollow shaft of this worm the gases are drawn off. The feed of coal is so designed that it meets the off-coming gases and vapors, cooling them and returning the condensed heavy oils with the coal into the retort. It is claimed by the inventor that the condensates, since

they bear no free carbon or pitchy residues, will not clog the outlets.

The minimum capacity of this retort is set down at ten tons per day. The process is designed to produce a free-burning coke of not over 2 per cent. volatile matter, a high yield of oils, a fair yield of ammonia, and about 8000 cubic feet of 750 to 800 B.t.u. gas.

The Petersburg plant is expected to operate commercially in conjunction with the local gas works and turn its gas into the city

FIG. 5.



High-temperature, ordinary blast-furnace coke, made in by-product ovens, from Lower Connellsville (Pa.) coal, 100 per cent.

mains. It is a process wherein low-temperature carbonization is combined in an ingenious manner with certain features of high-temperature carbonization, and its practical development is to be awaited with special interest.

In England much attention is being given to the development of processes wherein producer gas or water gas is made in a common generator with a low-temperature carbonization of the charge in its upper sections. The hot gases from the generator section pass upward and transmit their sensible heat to the raw coal above, thus in a measure carbonizing it.

Gas is obtained of low B.t.u. value but in large yields, and there is claimed to be also a large yield of valuable tar oils.

The Lymn process, a modification of the Mond by-product producer, is one of these, and is projected as especially adapted to large central station power development with gas-fired boilers.

The McLaurin producer is another of this type, now being installed in a large plant in the City of Glasgow.

The Bussey producer, developed in this country, but still on an experimental basis, also is of the type of process which makes a large yield of low B.t.u. gas, and may, as desired, give a yield of coke in greater or less amount, according to the method of operating.

Proposal is often made, in connection with projected large-scale power development, or central station development for gas, at the coal mines, to utilize some such process as those above mentioned, whereby the coal is gasified completely, with a by-product of tar and possibly ammonia. Duplex plants are possible, using low-temperature carbonizing retorts together with gas producers or water-gas generators, or, as above explained, a single combination process. It is problematical whether such central gas-distributing stations, by use of cheap coal and the saving of a certain amount of tar oils and ammonia, could thereby secure a sufficient advantage to offset the high cost of the gas-distributing lines and the carbonization plant investment.

Otto Hehner.—C. A. MITCHELL (*Analyst*, 1924, xlix, 501–505) has written a biographical sketch of Otto Hehner, who died September 9, 1924. Hehner was a pioneer in the study of foods and their adulteration. He made contributions to the chemistry of fats, meat extracts, honey, beer, vinegar, milk, butter, water, food preservatives, and beeswax. He devised the dichromate method for the determination of the glycerol content of fats. In 1874 Hehner discovered that butter fat differs from the body fat of animals in respect to the per cent. of insoluble fatty acids. The Hehner number, a fat constant based on this discovery, was the first procedure devised for the detection of the presence of a foreign fat in butter. J. S. H.

Test for Diethyl Phthalate.—JOSEPH T. RALEIGH and STANLEY U. MARIE (*Jour. Am. Chem. Soc.*, 1925, xlvii, 589–590) recommend the following presumptive test for the detection of the presence of diethyl phthalate in ethyl alcohol. A 100-c.c. sample of the alcohol is evaporated to a small bulk, then poured into a large volume of water, to which a few cubic centimetres of sodium hydroxide solution have previously been added. The formation of a milky cloud indicates the presence of diethyl phthalate. J. S. H.

THE AMPÈRE TROUGH EXPERIMENT AND ITS EXPLANATION BY THE USUAL ELECTRO-MAGNETIC LAWS.*

BY

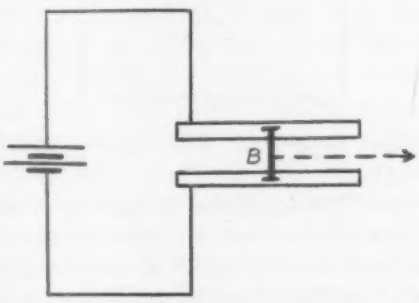
F. W. GROVER, J. P. DAS, and J. H. TURNBULL.

Union College.

In a recent paper in the *Journal of the A.I.E.E.*,[1] Dr. Carl Hering has made a plea for a revision of the fundamental laws of electromagnetic forces. In support of the suggested changes in his paper, he has described a number of original interesting and ingenious experiments which merit a close examination and study.

Of these experiments, that shown under Fig. 5 of his article is a modification of the classical Ampère trough experiment. In the form suggested by Ampère a copper wire is bridged

Fig. 1.



across two parallel mercury troughs to which a battery is attached. When the circuit is closed, the bridge, which floats freely on the mercury, moves to the right (Fig. 1). In Doctor Hering's modification the battery wires are so arranged that the bridge wire is now *inside* the rectangle formed by the battery wires. The effect of the current is still to send the bridge wire to the right (Fig. 2).

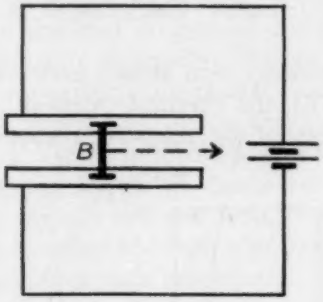
In commenting on the original experiment Doctor Hering

* Communicated by Frederick W. Grover, Ph.D., Associate Professor, Electrical Engineering Department, Union College.

[1] *Jour. A.I.E.E.*, 42, p. 139, Feb., 1923.

states that "the resulting movement of the wire B to the right was attributed to the old law that the circuit tends to enlarge itself, also to the repulsion due to that part of the battery wire which is parallel to the bridge wire. The writer attributes the motion to the tendency of the mercury parts of the circuit to lengthen, owing to the lateral pressure of the discs of flux around them; they are the only parts in which this force is free to act. This was shown to be the correct explanation, and the older explanations were shown to be wrong, by reversing the position of the battery circuit . . . . as the motion was then in the *same* direction, as it should be, while according to both the older laws

FIG. 2.



it should have been reversed. The battery wires should not be too near the troughs."

The old accepted law applicable to this experiment is that given by Maxwell [2] and quoted in many textbooks, namely, that "every portion of a circuit is acted on by a force urging it across the lines of magnetic induction so as to include a greater number of these lines within the embrace of the circuit," or as it is often given, that every circuit tends to move so as to embrace the maximum possible amount of flux. The statement above referred to by Doctor Hering, that a circuit tends to enlarge itself, is not an accurate statement of Maxwell's law and is true only of certain special cases. Such an explanation of the present experiment is justly condemned by Doctor Hering. In both forms of this experiment, the flux density at different points of the area enclosed by the circuit depends upon the position of the bridge wire and the length of the mercury troughs included in the circuit, and it is

[2] *Elect. and Mag.*, II, para. 490.

dangerous to attempt to decide from a mere inspection of the circuit whether or not the total embraced flux, that is, the integral of the flux density over the enclosed area, is increased or decreased by a given movement of the bridge wire. To obtain a definite answer to this question in any case, the natural method would seem to be to calculate the inductance of the circuit for different positions of the bridge wire, since by definition for constant current (as is here assumed), the inductance is proportional to the total flux linkages with the circuit.

The present paper gives the results of experiments made on the modified form of Ampère trough, together with an analysis of its behavior by means of the accepted electromagnetic laws. Not only are the changes of the inductance with different positions of the bridge wire investigated, but the variations of the force moving the bridge wire are studied by means of the usual equations.

EXPERIMENTAL RESULTS.

The circuit with which most of the measurements were made consisted of No. 8 B. and S. copper wire bent to form a rectangle 70 cm. by 25 cm. One side of the rectangle was interrupted by two parallel mercury troughs 1 cm. deep, 4 cm. wide and about 50 cm. long. These were placed symmetrically at the middle of the longer side of the rectangle, 5 cm. apart between centres, and a bridge wire of copper 5 cm. long spanned from one trough to the other. From the middle of the opposite side of the rectangle two long lead wires were carried closely, side by side, to the source of current. For the latter both d.c. and a.c. of 60 cycles were used, a lamp bank serving to control the current which was not carried beyond about 150 amperes. No noticeable differences were detected between the two cases. Considerable trouble was experienced from surface tension effects unless wide troughs were used. These were a disadvantage from the standpoint of the mathematical analysis. It was also found that if the bridge wire was suspended by threads from the ceiling (some three or four metres above the troughs), the motion of the bridge wire was more definite and reproducible. The plan of the apparatus is shown in Fig. 3. In this, for convenience of reference, the different elements of the circuit are numbered. The position of the bridge wire PQ will be in every case designated by its distance

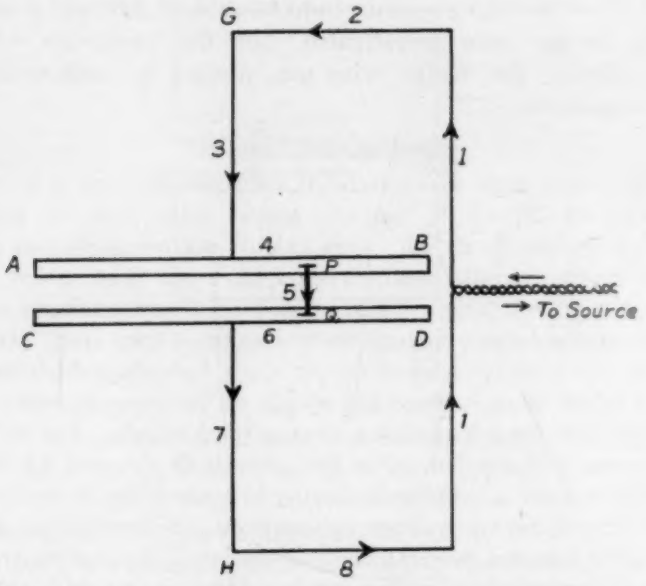
measured from the line *GH*. The observations of the force on the bridge wire are summarized in the following short table:

Distance from *GH*.	Direction of Force.
More than 1 cm. outside	Force away from *GH*
From 3 cm. to 20 cm. inside	Force away from *GH*
From 20 cm. to 24.5 cm. inside	Force toward *GH*

With the bridge wire outside the rectangle the arrangement is that of the original Ampère experiment. Doctor Hering's modification is represented by the arrangement when the bridge wire is inside the rectangle.

With the bridge wire close to the line *GH* (zero position),

FIG. 3.



the force observations were somewhat erratic. The general tendency was for the bridge wire to return to the line *GH*. It is shown later that, in this region, the force is changing rapidly, both in magnitude and direction, with small displacements of the bridge wire. The first and second items in the above table show the regions where the forces are in agreement with Doctor Hering's description of the experiment. He specifically excludes from consideration positions where the wires of the circuit have a

noticeable effect. For completeness the analysis here given will, however, cover the whole range of positions, since with a circuit of the dimensions here used the effect of the various elements of the circuit are all appreciable.

To confirm the inductance calculations, discussed in the next section, measurements of the inductance of the circuit were made which may best be described at this point. A Hartley vacuum tube oscillating circuit was used as a source, giving a frequency of about two million cycles per second. To this was coupled by a single turn of wire the Ampère trough circuit, a low resistance hot-wire ammeter of 1 ampere range, a General Radio Co. variable air condenser of 500 micromicrofarads range in parallel with a vernier condenser of 50$\mu\mu$f. range, all forming together a resonance circuit. It was found possible to obtain great sensitiveness, tuning this to the third harmonic of the source. As the total inductance of the circuit was only about three microhenrys, the inductance changes to be measured were very small. These were measured by determining the change necessary in the setting of the vernier condenser to restore resonance when the bridge wire was moved a noted distance. The apparatus was sensitive enough to allow a change of inductance of the order of better than 0.01 microhenry to be detected. The results of these measurements are shown below.

CALCULATION OF THE INDUCTANCE CHANGES.

Since what is desired is not so much the actual value of the total inductance of the circuit in any individual case as the change in the inductance of the circuit for different positions of the bridge wire, the inductance of the circuit with the bridge wire in the zero position was taken as a reference value. This value, calculated by the regular formula for the inductance of a rectangle, was 2.054 microhenrys. Denoting this by L_o, then the difference between L, the inductance with the bridge wire at a distance of D from the zero position, and the reference value is

$$L - L_o = 2(L_4 - M_{46}) + 4\,\Delta M_{35} - 2\Delta M_{13} - 4(M_{24} - M_{26}) \qquad (1)$$

In this formula L_4 is the inductance of one of the mercury troughs, M_{46} is the mutual inductance of the two mercury troughs, ΔM_{35} is the change in the mutual inductance of the bridge wire 5 and the wire 3, brought about by moving the bridge wire the distance D away from the zero position, etc. The formula

assumes that the wires 2 and 8, 3 and 7, 4 and 6, form pairs of wires of equal length.

Formulas are available for calculating all these component inductances. The usual formula [3] for calculating the inductance of the mercury trough applies strictly only to the case that the length of the trough is larger than the cross-sectional dimensions. An accurate formula was accordingly derived for calculating the values for short lengths of the mercury trough. The error from using the ordinary formula was not, however, greater than 10 per cent. in the worst case.

The results of these calculations are embodied in the inductance curve of Fig. 4, which gives the difference $(L - L_0)$ in millimicrohenrys (10^{-9} henry) as ordinates for different displacements D from the zero position. Measured values of the inductance obtained by the resonance method are shown by crosses, and are in reasonably good agreement with the calculated curve, considering the sensitiveness of the method.

A comparison of the observed directions of the force on the bridge wire with the inductance curve shows that Maxwell's principle is obeyed; the motion of the bridge wire is always such as to increase the inductance, that is, the linkages of flux. A similar conclusion was reached in experiments by Professor Morecroft, published in the discussion [4] of Doctor Hering's paper after the work here described was completed. It should be stated that in the discussion of his paper (page 1197) Doctor Hering affirms that the bridge wire moves in this experiment in such a direction as to increase the flux.

CALCULATION OF THE FORCE ON THE BRIDGE WIRE.

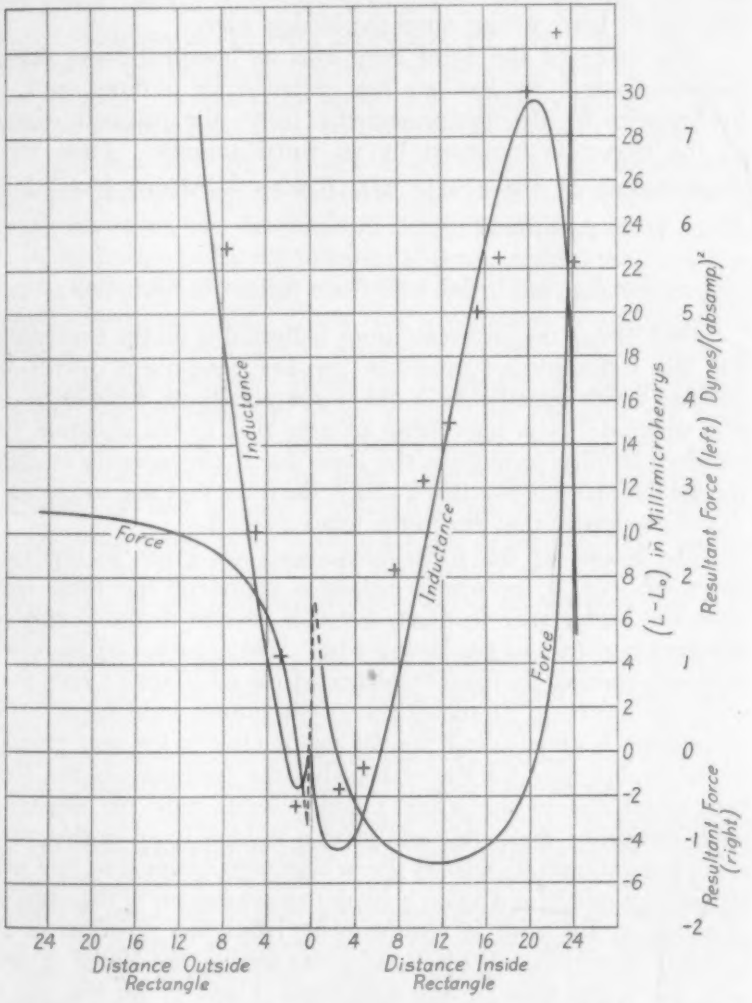
A clearer insight into the relations involved in the experiment is gained from a calculation of the total force exerted upon the bridge wire. By the accepted laws, the force upon each element of the bridge wire is, since the magnetic field intensity is, for points in the plane of the rectangle, perpendicular to the plane of the rectangle, equal to the product of current, magnetic field intensity and the length of the element, its direction being found in the plane of the rectangle by, say, the Fleming left-hand rule. The resultant field intensity at any element is, however, the sum

[3] Bureau of Standards Scientific Paper 169, p. 153, and Circular 74, Formulas 180–182.

[4] *Jour. A.I.E.E.*, **42**, p. 1191, Nov., 1923.

of the contributions of the other elements of the circuit, so that the force may be written equal to a sum of terms. That is, the force on the bridge wire may be found by summing the com-

FIG. 4.



ponent forces due to the separate wires of which the circuit is formed.

The expression for the field intensity at any point due to a

current in a straight wire is well known.[5] Integrating this formula along the length of a second straight wire gives the force exerted by one wire upon the other. This process was carried out for each of the wires of which the circuit is formed, and thus general expressions were found for each of the components of force acting upon the bridge wire.

The value of the force may also be obtained from energy considerations. By Kelvin's law, when work is done upon the bridge wire by the electromagnetic force, the magnetic energy of the circuit is increased by an equal amount. Thus for a displacement of the bridge dD, $F.dD = \frac{1}{2} I^2 dL$ or, $F = \frac{1}{2} I^2 \frac{dL}{dD}$. Thus, from equation (1),

$$F = I^2 \frac{d}{dD}[(L_4 - M_{46}) + 2\,\Delta M_{38} - \Delta M_{15} - 2\,(M_{24} - M_{26})] \qquad (2)$$

Performing the differentiations indicated upon the expressions for the inductances, equations for the component forces are derived which exactly check the force equations derived by the first method. It is interesting to note that in the equation just obtained the first term gives the force due to the mercury troughs, the second that due to wires 3 and 7, the third that due to the wires 1, and the fourth that due to the wires 2 and 8.

The results of the force calculations are given in the force curve of Fig. 4, in which ordinates represent the total force upon the bridge wire in dynes per unit current in the circuit for different positions of the bridge wire. The accuracy of the calculations is checked by the coincidence of the positions of zero force with the positions of maximum or minimum inductance. The force curve is given dotted for the region close to the zero position of the bridge wire for the reason that the formula for the force component due to the wires 3 and 7 holds only for negligible cross-section of the wires, and gives a sudden jump in this force from a maximum to zero as the bridge wire comes into line with the wires 3 and 7, and again a jump to a maximum in the opposite direction as the wire is moved away from this position in the opposite direction. With finite cross-section the force is zero with the bridge wire in line with wires 3 and 7, but the rise of force to a maximum, as the wire is moved in either direction from the zero position, is not so abrupt, nor is the maximum value so

[5] *Bull. Bureau of Standards*, 4, p. 303, 1907.

great, as in the case of zero cross-section. An exact formula for this case is not available, but an approximate investigation gave the result shown in the dotted curve.

The numerical results for the component forces will not be here given, but the following sketch will bring out the principal facts. With the bridge wire about 20.8 cm. from the zero position, inside the rectangle, the force to the right, due to the mercury troughs, amounts to about 2.85 dynes/ampere.[2] It is offset by a force of 0.5 due to the combined effects of sides 2,8 and 3,7 and a force of 2.35 due to the sides 1. If the distance from the zero position be increased, the force due to the sides 1 rapidly increases, and the resultant is toward the left.

If the bridge be moved toward the zero position, the force due to sides 1 rapidly decreases, while that due to the mercury troughs remains fairly constant. Thus, for a considerable distance, the resultant force is determined principally by the force component of the mercury troughs. When the distance from the zero position has been decreased to about 5 cm. from the zero, the component due to the mercury trough begins to decrease more rapidly, while that due to the sides 3 and 7 becomes rapidly more important, so that balance is reached at about 2.5 cm. from the zero position with a force to the right due to the mercury troughs, of about 2.05, while that due to the wires 3 and 7 is about 1.51 to the left and the combined effect of wires 2,8 and 1 is only 0.54 to the left.

In passing through the remaining distance to the zero position, the force due to the mercury troughs falls steadily toward zero, while the force due to the sides 3 and 7 increases and reaches a maximum a few millimetres from the zero position, and then falls rather suddenly to zero as the bridge wire reaches the zero position. Thus the resultant force in this interval reaches a maximum not far from the zero position, and then falls suddenly. At the actual zero position its value is 0.49 to the left, due to the wires 1 and 2,8 alone, but shortly after passing through the zero position to the outside of the rectangle, the force due to wires 3 and 7 springs to its maximum value (now to the right) and the resulting force reaches a maximum value to the right. Moving the bridge wire somewhat farther outside the rectangle, the force due to the mercury troughs again becomes appreciable and increases with the distance from the zero position, while the oppo-

site force due to wires 3 and 7 decreases. Balance is reached at a distance of about 1 cm., and for all distances outside the rectangle greater than this, the force component due to the mercury troughs is the controlling factor, and the resultant force is to the left.

CONCLUSION.

This analysis accounts for the observed facts of the experiment by applying the accepted laws of electromagnetic forces only. In so far as a comparison may be made with the views expressed by Doctor Hering, the main point at issue is the explanation of the contribution of the mercury troughs to the force on the bridge wire. To explain this Doctor Hering advances the theory of a longitudinal force or "stretch effect," while it has been shown by this work that the usual force on a wire carrying current and placed in a magnetic field is sufficient to account for the observed facts. This does not, of course, disprove the existence of a stretch effect. The fact that such a force is in agreement with Faraday's idea of a repulsion between lines of force suggests that this may be only another way of looking at the matter. It is difficult to see how an experiment of this kind can conclusively prove or disprove the existence of a stretch effect, but it is possible that a quantitative study of some of the others of Doctor Hering's ingenious experiments may yield decisive results. An investigation along these lines, including actual measurements of the values of the observed forces, should yield interesting results.

Absorbent for Oxygen.—LOUIS F. FIESER, of Harvard University (*Jour. Am. Chem. Soc.*, 1924, xlvi, 2639–2647), recommends an alkaline solution, containing sodium hyposulphite (hydrosulphite $Na_2S_2O_4$) and sodium anthrahydroquinone beta sulphonate, as an absorbent for oxygen in gas analysis. The sulphonate functions as a catalyst. The concentration of the reagents in the solution is varied with the type of apparatus used. J. S. H.

Organic Hypochlorites.—M. C. TAYLOR, R. B. MACMULLIN and C. A. GAMMAL (*Jour. Am. Chem. Soc.*, 1925, xlvii, 395–403) find that hypochlorous acid reacts with monohydric alcohols to form esters; tertiary alcohols yield more stable hypochlorites than do either primary or secondary alcohols. Hypochlorites of dihydric alcohols and trihydric alcohols could not be obtained. J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

SIMPLIFIED PRACTICE RECOMMENDATION ON HOTEL CHINAWARE.[1]

[ABSTRACT.]

INTEREST in the application of simplication to hotel chinaware originated through an address by a representative of the American Hotel Association before the 1923 annual convention of the American Ceramic Society at Pittsburgh, Pa. A proposal to go forward with a definite program of simplification of hotel chinaware was presented to the convention and received its indorsement. A recommendation that a committee of the Hotel Association meet with representatives of the American Vitrified China Manufacturers' Association in New York, N. Y., on April 10, 1923, was also unanimously passed.

The committee of the Hotel Association met with the manufacturers on April 10th, and the simplification program received the approval of the latter group. A committee of manufacturers was immediately appointed and authorized to proceed in coöperation with the committee of the Hotel Association.

These two committees, being confronted with the problem of dimensional simplification of varieties and types of hotel chinaware, requested the services of the division of simplified practice of the Department of Commerce, as a medium for the accomplishment of the movement. They were of the opinion that this project might be made one of the extended series of simplifications requested by various industries and directed toward waste elimination. This work is being carried forward jointly by the United States Chamber of Commerce, the American Engineering Standards Committee, and that division of the Department of Commerce.

A joint meeting of these committees was held in New York, N. Y., on May 7, 1923, under the auspices of the division of simplified practice and resulted in the formulation of a proposed list of types of hotel chinaware to be used as a basis for discussion at a general conference. It was the sense of that meeting that a

* Communicated by the Director.

[1] Simplified Practice Recommendation No. 5. Price, five cents.

general conference should be held in Washington, D. C., on May 28, 1923.

The general conference was attended by representatives of manufacturers, distributors, users, and other interested groups. Some 700 samples of hotel chinaware, representative of 200 variations commonly merchandized, were before the meeting, and after thorough discussion the conference crystallized its unanimous opinion in the following resolution:

> *Whereas* the Vitrified China Manufacturers Association in coöperation with the American Hotel Association and other interested representatives have met with and at the invitation of the Secretary of Commerce and the chief of division of simplified practice for the purpose of considering the simplification of hotel chinaware in the interests of economy; Therefore be it
>
> *Resolved*, that as a step toward the elimination of excess varieties of hotel chinaware, this conference unanimously recommends the establishment of the sizes and varieties as standard for hotel use. Furthermore, be it
>
> *Resolved*, that the Vitrified China Manufacturers Association and the American Hotel Association hereby commend the constructive coöperation of the division of simplified practice of the Department of Commerce, in lending its assistance to our effort to eliminate waste through the reduction of variety in hotel chinaware, and likewise commend the Chamber of Commerce of the United States for the helpful service rendered in this connection.

SIMPLIFIED PRACTICE RECOMMENDATION, No. 17, FORGED TOOLS.[1]

[ABSTRACT.]

THE project is one of the extended series of simplifications requested by various industries and directed toward waste elimination which is being carried forward jointly by the United States Chamber of Commerce, the American Engineering Standards Committee, and the Division of Simplified Practice of the Department of Commerce.

The industrial and economic value brought about through the

[1] Simplified Practice Recommendation, No. 17. Price, five cents.

reduction of excessive variety, type, and size; the improvement of manufacturing processes, and lessening of costs through the dropping of items infrequently called for; and the advantage of reducing catalogue numbers to those which indicate a definite consumer demand, brought about a request from the Forged Tool Society for a general conference of manufacturers, distributors, and users of forged tools, to be called by the Division of Simplified Practice, of the Department of Commerce, to consider the elimination of unnecessary, obsolete, and infrequently-called-for items produced by this industry.

As a precedent to this request, manufacturers, representing approximately 90 per cent. of the forged-tool manufacturing capacity of the United States, had met in New York on September 12, 1923, and again at Atlantic City on October 16, 1923, to consider a recommended preliminary program of simplification and elimination in this industry. The summary of the simplification and elimination program recommended to the Division of Simplified Practice as a basis for the consideration of the conference indicated a proposed elimination of 30 per cent.

The members of the conference discussed the tools listed under their several classifications item by item, and effected a more complete and satisfactory elimination than proposed in the original recommendation.

The final elimination approximated about 46 per cent., and the new schedule is effective July 1, 1924.

STANDARD DENSITY AND VOLUMETRIC TABLES.[3]

[ABSTRACT.]

BUREAU of Standards Circular No. 19 (sixth edition), "Standard Density and Volumetric Tables," contains standard density tables and others of a similar nature most often required in physical and chemical laboratories.

The tables given are based either on work done by the bureau or on work done by others, in which case due reference is made to the author or to the publication from which the information has been obtained.

Fifty-four tables are included, giving information pertaining

[3] Circular No. 19, sixth edition. Price, fifteen cents.

to the density of water from 0 to 102° C.; the density of various percentages of ethyl alcohol at various temperatures; the per cent. by volume and per cent. by weight of ethyl and methyl alcohol solutions of known density; the density and pounds per gallon of milk and cream and of petroleum oils; temperature corrections to the indications of hydrometers in alcohols, sugar and sulphuric acid solutions, and petroleum oils; the relation between specific gravity and degrees Baume for both heavy and light liquids; the relation between specific gravity and degrees A. P. I. for petroleum oils; the capacity of glass vessels from the weight of water contained or delivered at various temperatures; the volume of milk and cream at various temperatures occupied by unit volume at 68° F. (20° C.); master scales for the graduation of hydrometers to indicate percentages of ethyl alcohol by weight or by volume or percentages of proof spirit.

THEORY AND PERFORMANCE OF RECTIFIERS.[4]

By H. D. Holler and J. P. Schrodt.

[ABSTRACT.]

THE demand for small rectifiers during recent years has resulted from the increasing use of small storage batteries and also from the increasing practice of charging larger batteries at low rates. The purpose of this investigation was (1) to obtain data on the performance of the most common types of rectifiers on the market and (2) to explain the principles underlying their operation. The rectifiers studied included the electrolytic, magnetic, and ionized-gas-bulb rectifiers. Because of the adaptability of the electrolytic rectifier to the study of the underlying principles of rectification and also because of its possibilities, a considerable portion of the work was done on this type. By means of the oscillograph, the effects of various factors upon the wave-form and degree of rectification were determined. The aluminum rectifier, when properly used, is satisfactory for low rates of charging, such as is required for "B" batteries, but it has a short life. The tantalum rectifier, which is capable of carrying higher currents, is more resistant to the action of the electrolyte and, therefore, has a longer life.

[4] Technologic Papers, No. 265. Price, twenty cents.

The completeness of rectification may be expressed as the ratio of the average value to the root mean square or effective value of the rectified current. This ratio is called the "degree of rectification." A permanent magnet ammeter gives the true average value of any rectified current, as was proven by the use of a copper coulometer in series with the instrument. The degree of electrolytic rectification increases with the current density on the rectifying electrode and also with the amount of inductance in the circuit. It decreases at higher frequencies, and also with increasing battery voltage. An excessive temperature also reduces the rectification. While inductance without an iron core increases the degree of rectification, an inductance with an iron core having a high hysteresis loss reduces the degree of rectification somewhat, although the energy efficiency may be increased. The highest energy efficiency is obtained by reducing the line voltage to the proper operating voltage of the rectifier, either by means of a series reactance or a transformer. The energy efficiency, as used here, is the ratio of the power output (product of battery voltage and charging current) to the power input as indicated by a wattmeter.

The performance of all the rectifiers studied was determined at different battery voltages. The battery voltage required to reduce the charging current to zero corresponds to the peak value of the impressed voltage and suggests the use of the rectifier for measuring peak voltages. The curves obtained by plotting power output against battery voltage are of the same shape for all types of rectifiers. The power output in each case increases from zero (at zero battery voltage) to a maximum and decreases again to zero (at the battery voltage required to reduce charging current to zero). Equations showing the relation between battery voltage and power output are derived and the battery voltage for a maximum output may be computed. The battery voltage at which maximum output is obtained is practically the same as the voltage at which the rectifier is rated by the manufacturer.

Since the power input is almost a linear function of the battery voltage, and the efficiency is the ratio of output to input, the curve obtained by plotting efficiency against battery voltage also passes through a maximum, but at a higher voltage than that at which maximum output is obtained.

The performance of the vibrating rectifiers was determined

over a considerable range in frequency and line voltage. Since any failure to operate properly is immediately shown by a reduction in efficiency, the efficiency is the best index of performance. The efficiency was, therefore, plotted against the line voltage and frequency as well as battery voltage. Variation in line voltage and in frequency is permissible over a considerable range without an appreciable reduction of efficiency, except in the case of one rectifier. An increase in line voltage reduces the efficiency, while a decrease in line voltage, below the rated value, raises the efficiency slightly. With a too low line voltage, the rectifier ceases to rectify. Variation of efficiency with frequency shows that the efficiency is usually reduced when operating too far above or below the rated frequency. In one case the efficiency is unchanged over a considerable range of frequency, while in another case rectification ceases with a decrease in frequency of only two or three cycles.

The magnetic vibrating rectifier which is essentially a synchronous switch, opening and closing in synchronism with the voltage to be rectified, must have a natural frequency considerably removed from the frequency at which it is to be used. If a frequency is used corresponding to its natural period, the switch may open and close at the peak of the wave and no rectification is obtained. The farther the natural frequency is removed from the operating frequency, the more independent is the rectifier of any variation in frequency. The phase relations required to obtain rectification are discussed.

A set of conventional curves is given which may represent the performance of any rectifier regardless of its type. The effect of various factors upon rectification is demonstrated by means of numerous oscillograms and diagrams as well as performance curves.

UNITED STATES GOVERNMENT MASTER SPECIFICATION FOR LIQUID SOAP (FOR LAUNDRY USE).[8]

THIS specification was prepared by a technical committee of the Federal Specifications Board in coöperation with the soap committee of the soap section of the American Specialty Manufacturers' Association and with other manufacturers, and was promulgated by the Federal Specifications Board on November 5,

[8] Circular No. 193. Price, five cents.

1924. The specification covers one type of soap made of high-grade materials, and gives the general requirements and detailed methods of inspection and testing, the preparation of the reagents required, and the basis of purchase. The methods of inspection and testing were prepared by a committee of the American Chemical Society in coöperation with the two committees mentioned above. The general requirements are:

The soap desired under this specification is a clear solution of pure potash (or potash and soda) soap with or without glycerol or alcohol and containing not less than 12 per cent. by weight of a volatile organic solvent or a mixture of such solvents. It shall yield a clear solution on mixing with soft water, shall quickly form a satisfactory lather, shall have no injurious effect and leave no objectionable odor on fabrics. Materials washed with this soap shall have, after drying, a soft feel and not appear more boardy or stiff than when washed with soft water. The detail requirements are:

Failure to meet any of the following requirements will be cause for rejection:

The material shall be a clear solution, shall yield a clear, homogeneous solution on mixing with soft water, shall quickly form a satisfactory lather, and shall leave no objectionable odor on fabric.

Total anhydrous soap shall be not less than the equivalent of 24 per cent. potash soap.

Total matter insoluble in alcohol shall not exceed 0.5 per cent.

Free alkali, calculated as potassium hydroxide (KOH), shall not exceed 0.05 per cent.

Chloride, calculated as potassium chloride (KCl), shall not exceed 0.3 per cent.

Total matter insoluble in water shall not exceed 0.1 per cent.

Volatile organic solvent shall be not less than 12 per cent.

All constituents shall be calculated on the basis of the original sample.

Washing test: Fabric washed with the liquid soap shall show no more shrinkage or felting than occurs with similar fabric washed with soft water at the same temperature. Colored materials when washed with this soap shall not fade more than when washed the same number of times at the same temperature with soft water alone.

DESIGN OF SPECIMENS FOR SHORT-TIME "FATIGUE" TESTS.[6]

By L. S. Tuckerman and C. S. Aitchison.

[ABSTRACT.]

ALTHOUGH the so-called "short-time fatigue test" apparently will not replace the endurance-run test, sufficient correlation between the two types of test has been found to make further study worth while.

The controlling factors in the design of specimens are different for the short-time "fatigue" tests and endurance-run fatigue tests. These differences are discussed in a previous Technologic Paper of the Bureau of Standards.

In endurance runs it is necessary to secure failure at a place where the stresses are determinate and calculable. The highest maximum of stress lies on a free portion of the specimen far enough from the clamps to be calculated by the elementary Euler-Bernoulli theory. The shape of the specimen must also provide for a maximum of stress sufficiently removed from clamps and fillets to be calculated by this simple theory and large enough to exceed any local stresses near the clamps.

In the short-time "fatigue" tests failure is not desired. There is, therefore, no necessity of providing a maximum of stress on a free portion of the surface of the specimen. In addition, the indeterminate stresses concentrated in the neighborhood of the clamps contribute only a small part to the deflection or temperature rise, so that there is no practical disadvantage in allowing them to be higher than those in the uniformly stressed free portion of the specimen. Those limitations which determine the design of endurance-run specimens, therefore, do not apply to short-time tests. It is possible, then, to design a specimen for this test with maximum stresses uniform over a large portion of the material, thus securing greater sensibility. This should be the controlling factor in the design of these specimens.

Specimen shapes are shown suitable for different types of short-time "fatigue" tests. Because of the simple specimen shape the Sondericker type of machine is deemed best suited for these tests.

[6] Technologic Papers, No. 275. Price, five cents.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

DESENSITIZERS AND DISTORTIONS ON PLATES DUE TO LOCAL DESENSITIZING.[1]

By Frank E. Ross.

THE author states the desirable characteristics of desensitizers for astronomical purposes and deals briefly with the theoretical phase of the subject pointing out the essentially different action of desensitizers and those substances which destroy the latent image. The experimental results obtained by using copper sulphate as a desensitizing agent show that the extent of desensitization can be controlled over a wide range of values by proper adjustment of the treatment. Under certain conditions a marked increase in gamma is obtained which is desirable for certain types of work. The ratio of speed before desensitizing to the speed after desensitizing may be varied from 13 up to 320.

The desensitizing power of phenosafranine and of pinakryptol green was found to be about the same. Since pinakryptol green does not stain the negative it is preferred, a concentration of 1:25,000 giving a reduction of speed to 2.5 per cent. of the original value.

A solution of chromic acid (concentration, 0.5 per cent.) reduced the speed to 1/10,000 of its original value, and with this treatment it was found possible to obtain satisfactory density gradation in the region of exposure which is normally overexposed, or even reversed. A discussion is given of dimensional distortions due to local densitization of "spotting." Under certain conditions large distortions may result, while if proper precautions are taken these may be completely eliminated.

The Decay of Radium. E. L. BASTINGS. (*Phil. Mag.*, Dec., 1924.)—This descendant of radium manifests certain peculiarities in the matter of its β-ray emission. When these rays are subjected to a transverse magnetic field and are thereby spread into a spectrum, this spectrum turns out to be continuous and without those lines

* Communicated by the Director.

[1] Communication No. 220 from the Research Laboratories of the Eastman Kodak Company and published in *B. J. Phot.*, 72: 5–6, 19–21 (1925).

that have been found in the spectra of all other bodies emitting β-rays except UrX. A second idiocyncrasy lies in the exceedingly small ionizing power of its γ-rays in comparison with that of its β-rays. The former have an effect equal to about .02 per cent. of the latter, whereas in all other β-ray substances the relation lies between 2 and 100 per cent.

"It is now generally considered probable that the β-rays comprising a line-spectrum are ejected from extranuclear orbits by the action of γ-rays proceeding from the nucleus, and owe their varied velocities to their originating from different energy-levels of the atom. But in the case of RaE, as with other continuous β-ray spectra, all the β-rays probably have their origin in the nucleus itself, and it is not easy to see how such great differences in velocity can arise in the disintegration of nuclei presumably all alike. Now one important respect in which the atoms are assumed to be alike is implied in the exponential law of decay, *viz.*, that all the atoms present have the same probability of decay, irrespective of any attendant circumstances. But a conceivable explanation of the heterogeneity of the rays might be found in the assumption that the atoms do not all possess exactly the same probability of decay; that, for example, the atoms evolving fast β-rays might disintegrate at a more rapid rate than those ejecting slow particles, and in consequence possess a decay constant differing from the average constant, as deduced from the usual decay measurements." To test this hypothesis the rapid rays from RaE were filtered out by passage through sheets of aluminum and a comparison was made between the decay of these rapid rays and that of the continuous spectrum of rays. No difference could be detected. "We are therefore still without any adequate explanation of the homogeneity of the β-rays in the continuous spectrum of this or other β-ray products." In addition the time required for RaE to transform itself to the extent of one-half was determined. The half-period is given as 4.98 days.

G. F. S.

Geber.—According to E. J. HOLMYARD (*Sci. Prog.*, 1925, xix, 415–426), the alchemist known in English as Geber was Abu Musa Jabir ibn Hayyan, a member of the court of the Caliph Harum al Rashid. He was of Persian extraction, and lived from 730 or 740 to about 810. He was the greatest chemist of Islam. The Latin treatises ascribed to him are based on Arabic knowledge, but are not literal translations from Arabic texts. These Latin treatises and the Arabic works ascribed to Jabir are strikingly similar in content.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE SPONTANEOUS DECOMPOSITION OF BUTTER FAT.[1]

By C. A. Browne.

[ABSTRACT.]

THE results of periodic analyses of butter fats which had been exposed to the air in light and darkness, at room temperature since 1897, showed marked increases in the content of free and volatile acids and a considerable decrease in the content of insoluble acids. The insoluble acids from old butter fats all showed pronounced ester and acetyl numbers, indicating the presence of fatty anhydrides or lactones and hydroxyacids. Butter fats exposed to the atmosphere in a thin layer gained rapidly in weight during the first year from absorption of atmospheric oxygen. This gain continued during the summer months of the second year, but after September the fats began to lose in weight, until February, when another period of increase commenced. This alternate rise and fall in weight, largely due to absorption and loss of hygroscopic moisture, continued indefinitely and followed exactly the humidity curve of the atmosphere. The maximum gain in weight for the fat in the light after four years and five months was 3.58 per cent.; thereafter an average annual loss in weight of about 0.2 per cent. occurred. The fats which showed the greatest loss in iodine absorption exhibited the greatest increase in free and volatile acids. The free insoluble acids of the decomposed fats contained oleic acid in nearly the same proportion as in the neutral fat.

The theory is advanced that the disintegration of the fats is primarily due to the action of active or nascent oxygen, one atom of which is liberated for each atom of oxygen absorbed at the points of unsaturation. A secondary cause of decomposition is the effect of absorbed moisture, the hydrolytic action of which rises and falls according to the humidity and temperature of the air.

* Communicated by the Chief of the Bureau.

[1] Published in *Ind. Eng. Chem.*, **17** (Jan., 1925) : 44.

INVERSION LOSSES IN CANE SUGAR MANUFACTURE.[2]

By C. F. Walton, Jr., M. A. McCalip, and W. F. Hornberger.

[ABSTRACT.]

Loss of sucrose due to inversion has been carefully investigated in a number of industrial procedures for cane sugar manufacture. Analytical methods of a suitable degree of precision have been selected, and the typical operations of defecating the juice, concentrating in multiple-effect evaporators and vacuum pan, and using a crystallizer, have been reproduced on a small scale, insofar as the controlling factors of time, temperature, pH, and sucrose concentration are concerned. The variation in pH of juice during the sequence of treatment from defecation to crystallization has been studied. The data indicate that in defecating cane juice for raw sugar manufacture the initial pH at which it is safe to carry the juice lies between 7.0 and 8.0, *i.e.*, at such a point that the resulting syrup has a pH value between 6.7 and 7.0. In the sulphitation process, by which direct consumption sugar is produced, a lower pH and correspondingly higher titrated acidity may be safely carried.

ACTION OF FATTY ACIDS AND OILS ON A PHOTOGRAPHIC PLATE.[3]

By Walter F. Baughman and George S. Jamieson.

[ABSTRACT.]

RUSSELL has shown that many substances produce a developable impression on a photographic plate when placed in proximity to it in the dark. He believed that the active substance is hydrogen peroxide. An investigation conducted in the Bureau of Chemistry shows that freshly expressed vegetable oils or fats do not have this property, but that after exposure to the sun for several hours they become active. The saturated fatty acids are inactive, even after exposure to the sun. On the other hand, the unsaturated fatty acids are faintly active before exposure to the sun and after such exposure become intensely active.

Heating to approximately 120° C. for several hours destroys or greatly decreases the activity. Blotting paper placed over very

[2] Published in *Ind. Eng. Chem.*, **17** (Jan., 1925) : 51.

[3] Published in *J. Oil Fat Indus.*, **2** (Jan., 1925) : 25.

active oils becomes permeated with the active substance and capable of affecting a plate.

The substance given off by an active oil will liberate iodine on a test paper saturated with a solution containing potassium iodide, starch, and a little ferrous sulphate. A paper saturated with titanium sulphate will be turned yellow by it, and one saturated with a solution containing ferric-ferricyanide will be turned blue, showing that there has been a reduction to ferric-ferrocyanide.

These results confirm Russell's opinion that the substance is hydrogen peroxide.

THE SPECTROPHOTOMETRIC DETERMINATION OF HYDROGEN-ION CONCENTRATIONS AND OF THE APPARENT DISSOCIATION CONSTANTS OF INDICATORS. II. THYMOL BLUE.[1]

By Walter C. Holmes and Edward F. Snyder.

[ABSTRACT.]

DATA have been obtained for a relatively convenient and accurate spectrophotometric method for determining the hydrogen-ion concentrations of solutions within the effective dissociation ranges of thymol blue.

The apparent dissociation constants of the indicator in its alkaline and acid ranges are 8.91 and 1.5, respectively.

The dissociation of the indicator is normal over its useful alkaline range, but is appreciably retarded after the mid-point in its acid range has been passed.

THE SPECTROPHOTOMETRIC DETERMINATION OF HYDROGEN-ION CONCENTRATIONS AND OF THE APPARENT DISSOCIATION CONSTANTS OF INDICATORS. III. BROMOCRESOL GREEN.[2]

By Walter C. Holmes and Edward F. Snyder.

[ABSTRACT.]

THE dissociation of bromocresol green conforms to the theoretical formula over the useful portion of its alkaline range.

The apparent dissociation constant of a relatively pure sample of the indicator of laboratory origin was determined as 4.68.

[1] Published in *J. Am. Chem. Soc.*, **47** (Jan., 1925): 221.

[2] Published in *J. Am. Chem. Soc.*, **47** (Jan., 1925): 226.

The values obtained with two commercial products were, respectively, 4.65 and 4.69.

THE SPECTROPHOTOMETRIC IDENTIFICATION OF DYES. II. BASIC FUCHSINS.[6]

By Walter C. Holmes.

[ABSTRACT.]

AN analytical scheme for the identification of the basic fuchsins is outlined and representative data are supplied.

Identification is based on the influence of constitutional variation in the dyes upon a series of spectrophotometric constants, which define significant differences in the absorption and behavior of the dyes.

THE INFLUENCE OF CONSTITUTIONAL VARIATION UPON THE ABSORPTION AND STABILITY TO HYDROGEN IONS OF CERTAIN HALOGENATED DERIVATIVES OF FLUORESCEIN.[7]

By Walter C. Holmes.

[ABSTRACT.]

ABSORPTION maxima are supplied for a comprehensive selection of halogenated derivatives of fluorescein in aqueous and alcoholic solutions. In the substitution within the phthalic anhydride residue the displacement of the maxima is influenced by the nature of the halogen concerned in a definite degree, but an appreciably less decided degree than in the substitution within the resorcinol residues. The effect of substitution in the resorcinol residues is not constant in degree under all conditions, but is modified by substitution within the phthalic anhydride residue. Substitution in the 1 and 8 (*h* and *i*) positions in the resorcinol residues is without appreciable effect upon the absorption. Substitution within the resorcinol residues increases the stability of the dyes in aqueous solution to the hydrogen ion, whereas substitution within the phthalic anhydride residue is of opposite effect. The relative stability of the dyes to acids is increased by the replacement of iodine by bromine and by that of bromine by chlorine.

[6] Published in *Ind. Eng. Chem.*, 17 (Jan., 1925): 59.

[7] Published in *J. Am. Chem. Soc.*, 46 (Dec., 1924): 2770.

THE PREPARATION OF METHYL-ISOPROPYL-ANTHRAQUINONE.[1]

By Max Phillips.

[ABSTRACT.]

1-methyl-4-*iso*propyl-anthraquinone has been synthesized from *p*-cymene and phthalic anhydride. The reaction proceeds in two stages: *p*-cymene and phthalic anhydride combine to form cymoyl-benzoic acid; this when condensed in the presence of sulphuric acid yields methyl-*iso*propyl-anthraquinone. Several derivatives of this anthraquinone have been prepared.

A New Determination of the Constant N of Avogadro, Based on Its Definition. PIERRE LECOMTE DU NOÜY, Rockefeller Institute for Medical Research. (*Phil. Mag.*, Oct., 1924.)—A few months ago the author made public the results of his study of the changes that take place in the surface tension of solutions of colloidal substances with the lapse of time. He found that a solution of sodium oleate of concentration 1/750,000 decreased more in its surface tension during the given interval than either stronger or weaker solutions of adjacent concentrations. The minimum thus attained he attributed to the oleate molecules arranging themselves on end upon the bounding surfaces of the liquid and in a single layer. He argued further that, if at this particular concentration the surface was neatly covered by a single layer of oleate molecules, the water molecules would find more difficulty in escaping through this continuous film existing between the air outside and the water inside that would be the case were the oleate molecules piled up on the surface as in more concentrated solutions or were they too few to cover the entire surface as in more dilute solutions. He tried this suggested conclusion and actually found the solution of 1/750,000 to evaporate more slowly than the neighboring solutions. He has now gone farther and discovered there are for solutions of sodium oleate two additional concentrations for which the surface tension after the passage of two hours is a minimum, so that now three minima are known to show themselves for the concentrations of 1/750,000, 1/1,220,000 and 1/1,390,000. The author's understanding of what takes place is this. Conceive the molecule of sodium oleate to possess the form of a brick $8 \times 4 \times 2$ inches. The first minimum corresponds to a film over the surface of contact of the solution with both glass container and air, the molecular bricks forming a pavement 8 inches deep with the dimensions of the bricks in the surface being 4×2 inches. In the other cases of minima the length of the brick is parallel to the surface

[1] Published in *J. Am. Chem. Soc.*, **46** (Nov., 1924): 2533.

of the pavement, the depth being either 4 or 2 inches, according to the method of arrangement. Then, on the assumption that every molecule after two hours of opportunity has located itself on the surface of the solution, the problem of calculating the dimensions of a molecule is solved just as would be this: "How much is the depth of a brick pavement to be found, it being given that a known weight of brick of known specific gravity covers a known number of square feet?" The mass of oleate in the solution is calculated from the concentration and volume. By this method the dimensions of the molecule are found to be $12.30 \times 7.56 \times 6.64$ hundred-millionths cm. By multiplying these together the volume of the molecule is obtained and the product of the volume by the density gives the mass of the molecule as 507×10^{-24} gram. A gram-molecule of the oleate contains 304.35 grams of it. The quotient of this, divided by the mass of one molecule, furnishes $6.003/10^{23}$ as the number of molecules in one gram-molecule, which is Avogadro's constant, N. "This value agrees within 0.1 per cent. with the value found by Millikan (6.062×10^{23}), which he considers as correct within ± 0.006."

This new determination, of course, stands or falls with the correctness of the assumption that all molecules of the oleate present in the solution are actually in the surface and that no molecules are elsewhere. There is, happily, a way to test the assumption. Consider the arrangement for the solution of 1/750,000 concentration. Here the dimensions of the ends of the molecules on the surface are 6.64×7.56 hundred-millionth cm. These two dimensions are derived from experiments with the other two minima of surface tension. In addition the number of molecules of oleate is obtainable by dividing the mass of it in the solution by the mass of one molecule. Then the product of the number of molecules present by the area of the end of one molecule gives the total area covered by the layer of oleate, and this can be measured directly. Calculation gives 26.40 sq. cm. and measurement 26.4 sq. cm. For the two other minima the calculated area comes to 26.40 and 26.39, respectively. It should be noted, however, that the volume of the molecule is, presumably, used to calculate its mass and that the volume is got by multiplying together the three dimensions and that one of these dimensions has been obtained from each of the three concentration experiments. The identity of the calculated with the measured area for each concentration is not, therefore, entirely independent of measurements made under the conditions of that concentration. The agreement would be practically as good, were Millikan's value of N used to calculate the mass of one molecule.

The certainty with which N and other molecular constants are now known and used is in amazing contrast with the doubt that was prevalent two or three decades ago. G. F. S.

NOTES FROM THE DEPARTMENT OF THE INTERIOR, BUREAU OF MINES.*

OXIDATION OF ZINC VAPOR BY CARBON DIOXIDE.

By B. M. O'Harra.

BECAUSE of the important effect of carbon dioxide on the condensation of zinc vapor in the metallurgical treatment of zinc ores, experiments were made to determine the concentration of carbon dioxide necessary to oxidize zinc vapor at various temperatures.

Although the preliminary experiments failed to give the quantitative information desired, they proved that the required concentration of carbon dioxide increased with rising temperature. It was found that zinc oxide was reduced at 750° C. by carbon monoxide even when carbon dioxide was present in large proportions, but that partial reoxidation took place in the cooler part of the reaction tube. The weight of zinc oxide reduced in a given time decreased with increasing ratios of carbon dioxide, and when 90 per cent. of carbon dioxide was present, the reduction and reoxidation was manifest only by a transfer of zinc oxide from the hot to the cooler part of the tube.

In the preliminary experiments with zinc, it was found that oxidation took place in the cooler parts of the reaction tube, even when the concentration of carbon dioxide was not enough to oxidize zinc in the hot part of the tube. It was furthermore found that all carbon dioxide was converted to carbon monoxide by reaction with zinc at some temperature between 750° C. and room temperature, if enough time were allowed for the completion of the reaction.

With the knowledge gained from these preliminary experiments a final series of experiments was planned, from which the desired quantitative data were obtained. These data were plotted and a curve drawn from which may be found the minimum concentration of carbon dioxide at any given temperature that will have an oxidizing effect on zinc vapor under the conditions of zinc condensation in metallurgical practice.

It has also been demonstrated that the oxidation of zinc vapor by carbon monoxide is theoretically possible, though this oxidation

* Communicated by the Director, Bureau of Mines.

is ordinarily of little practical importance. A fuller account of the experiments will be found in Technical Paper 336 of the bureau, which is now available.

THE PURIFICATION OF COPPER SULPHATE SOLUTIONS.

By George S. Tilley and Oliver C. Ralston.

ONE of the main deterrents in the use of sulphuric acid leaching and electrolysis for extracting copper from its ores has been the fouling of the solutions with soluble impurities of the ore, especially iron and aluminum. Any simple, inexpensive means of removing these two impurities would be useful in leaching and refining copper, in purifying bluestone-plant solutions, and in treating mine water that contains copper.

The writers, therefore, took up this problem. A study of previous work by various investigators showed that the removal of iron and aluminum, and incidentally arsenic, antimony, bismuth, and tin, from copper sulphate solutions, has been effected satisfactorily in a number of processes, but details were lacking on the best operating conditions, methods of controlling the reactions, or the basis of procedure.

The writers then selected for further research an investigation of hydrolytic agents, as the most promising field of work. The limitations of cost, availability, and suitability to other conditions limited the tests chiefly to carbonates and oxides of copper and calcium.

It was found that ferric iron and aluminum can be precipitated from copper solutions, and ferrous iron oxidized by aeration. The removal of ferrous iron was very slow, but the use of higher temperatures and fine-bubble aeration in an apparatus devised by the writers gave better results. Further tests on a commercial scale show that practically all of the iron can be removed, but as the reaction approaches completion, the rate of oxidation and removal becomes very slow. Further details will be found in Technical Paper 359, recently issued by the Bureau of Mines.

THE ELECTRICAL MANUFACTURE OF CARBON BLACK.

By J. J. Jakosky.

EXISTING and proposed legislation against the present method of producing carbon black from natural gas and the continually increasing demand for the gas for other purposes, indicate that

the supply of carbon black may gradually decrease and that new methods for its production should be developed. In the course of investigations of the effects of high-voltage electrical discharges on hydrocarbons, it was noted that, under certain conditions, natural gas could be decomposed and carbon black produced. The author therefore studied the effects of several types of electrical discharge on natural gas and on liquid hydrocarbons and other oils in order to ascertain the fundamental factors in the reactions. In the study of natural gas, the possible influence of these factors on the recovery of a larger part of the carbon content of the gas than is now possible was investigated.

In the experiments with natural gas, the best results were obtained with an apparatus in which transformer oil surrounded the arc. The electrodes were placed vertically one above the other, and immersed in oil, the lower electrode being hollow and forming the gas inlet. However, it was found that the efficiency was considerably higher when operating on oil alone.

In the improved apparatus worked out for making carbon black from gas oil, kerosene or other liquid hydrocarbons, the oil would be placed in a suitable storage tank and then pumped to counter-current gas scrubbers. From the header the oil would flow down through the scrubbers into the treating chamber. After passing through the arc or treating chamber the treated oil would flow to a settling tank. In the settling tank the clear oil would gradually rise to the top and pass out through an overflow, either back to the original storage tank or to stills for redistillation. The carbon from the settling tank could be drawn out near the bottom in the form of a sludge and then treated. The gas produced during the decomposition of the oil in the arc chamber would be passed through the scrubber, counter-current to the incoming oil, and out of the gas outlet at the top of the header. This gas coming from the arc chamber contains a large amount of carbon in suspension, and it was found that thorough scrubbing was necessary in order to remove it. In order to aid the scrubbing process it may be beneficial to have the entire system under pressure, in which case the pressure valve at the top of the header could be set for any value. The effects of pressure upon the carbon formation are not known, but it seems probable that a high pressure would tend to keep the oil in closer contact with the

arc, prevent much volatilization of the oil, and thereby insure higher efficiency.

For manufacturing carbon black from oils by the process described, the main essentials are cheap electric power and cheap light-oil distillates. As the process is simple, complicated special equipment is not necessary. Aside from the arc treaters themselves, apparatus for handling the oil and for the filtering, drying, and air separation of the black is of standard design. At most of the carbon-black works high-voltage current, such as is available at power plants, could be used directly and transformer stations would not be required, although suitable current-limiting reactances would be necessary.

Further details will be found in Technical Paper 351 of the bureau, which was recently published.

New Test for the Aluminum Ion.—L. P. HAMMETT and C. T. SOTTERY, of Columbia University (*Jour. Am. Chem. Soc.*, 1925, xlvii, 142–143), find that the ammonium salt of aurin tricarboxylic acid may be used as a reagent for the detection and identification of the aluminum cation. This salt reacts with aluminum salts to form a bright red color lake, which precipitates in the presence of an acetate-acetic acid buffer and is not decomposed in any reasonable time by the addition of ammonia. While chromium forms a similar color lake, the latter is decomposed and decolorized by ammonia. The precipitated aluminum hydroxide, obtained by the usual procedure of qualitative analysis, is dissolved in 5 c.c. of normal hydrochloric acid; 5 c.c. of triple normal ammonium acetate and 5 c.c. of a 0.1 per cent. solution of the ammonium salt of aurin tricarboxylic acid are added; and the liquid is thoroughly mixed. After the color lake has formed, the solution is made alkaline with ammonium hydroxide containing ammonium carbonate. A bright red precipitate, not decolorized by the ammonia, is formed by as little as 0.00002 gram-atom of aluminum, while a red solution, easily distinguishable from the yellow color yielded by the precipitant in the presence of alkalies, is given by smaller quantities of aluminum; the test may reveal the presence of as little as 0.000001 gram-atom of that metal in the form of a cation. In this test, a white precipitate is yielded by silicic acid, and by salts of lead, bismuth, bivalent mercury, tetravalent tin, antimony, and titanium; a red precipitate is given by large quantities of the salts of the alkaline earths, but is decolorized by carbonates; no precipitate is produced by salts of cadmium, manganese, zinc, cobalt, and nickel; a deep violet precipitate is formed by ferric salts, but is converted to a reddish-brown by ammonium hydroxide. J. S. H.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 18, 1925.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 18, 1925.

DR. WM. C. L. EGLIN, *President*, in the Chair.

The Board of Managers submitted its report. It recorded the election of seven gentlemen to membership.

The President announced that the next business of the meeting would be the presentation of the Louis E. Levy Medal to Dr. Harvey C. Hayes and recognized Dr. Geo. A. Hoadley. Doctor Hoadley, on behalf of the Committee on Science and the Arts, described the work of Doctor Hayes, and referred especially to that described in his paper on "Measuring Ocean Depths by Acoustical Methods" which appeared in the March, 1924, issue of the JOURNAL of the Institute and for which the medal was awarded. He was introduced to the President, who presented him with the medal and accompanying certificate. Doctor Hayes expressed his appreciation of the honor conferred upon him.

The meeting then became a joint one with the Engineers Club of Philadelphia and the Philadelphia Section of the American Society of Civil Engineers, and Mr. Charles H. Stevens, President of the Philadelphia Section of the American Society of Civil Engineers, was requested to take the Chair.

Mr. Stevens introduced Mr. Leon S. Moisseiff, C.E., Engineer of Design, who presented a paper on "The Towers, Cables and Stiffening Trusses of the Bridge over the Delaware River between Philadelphia and Camden." The paper was devoted to a consideration of the conditions governing the design of the bridge: Requirements of navigation, development of traffic over the bridge and materials available. The type of the structure and its æsthetic appearance were also considered. Reference was made to the design of the towers. Cables, their anchoring, saddles and suspension; the stiffening trusses, their function and behavior were discussed. Mention was also made of the evolution of the stiffening truss theories and the deflection theory, and its meaning and economic value.

Mr. Clement E. Chase, C.E., Principal Assistant Engineer, then presented a communication on "Research and Experimental Tests in Connection with the Design of the Delaware River Bridge." He described the tests made for the purpose of determining the best proportions and probable strength of the compression members composing the main towers and discussed the experiments made with the single cable wires to show their strength under various conditions of combined loading, reduced area and the efficiency of splices. Mention was also made of the wire rope and parallel wire strands which were tested in units of varying size to ascertain strength and efficiency. Model

cable sections were compacted in order to predict size of finished cable, and full-size tests were made to investigate secondary stresses induced by bending and the resistance of the cable bands against sliding. The papers were illustrated by lantern slides.

After a brief discussion, a rising vote of thanks was extended to the speakers, and the meeting adjourned.

GEO. A. HOADLEY,
Acting Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, February 4, 1925.)

HALL OF THE INSTITUTE,
PHILADELPHIA, February 4, 1925.

MR. HAROLD CALVERT in the Chair.

The following reports were presented for final action:

No. 2745: Hoke Method of Making Precision Gauges.

A comparatively few years ago the making of precision gauges, especially those of a high degree of accuracy, was in the hands of European tool-makers.

During the World War the demand for gauges was greatly increased and the supply was decreased. To meet the increased demand a method of making them was invented by Major William E. Hoke, of Washington, D. C. The gauges made by this method are one inch wide, of various lengths, and are guaranteed accurate within three-millionths of an inch.

They are made of high carbon-chrome alloy steel, glass hard and well seasoned. The final finishing is done on a lapping machine, the blanks being held in a cage which is submerged in a lubricant charged with a fine grade of abrasive. By interchanging the blanks in the cage they are finally reduced to a uniform thickness.

In consideration of the ingenuity displayed in the invention of a highly satisfactory method of producing precision gauges, The Franklin Institute awards its Edward Longstreth Medal to Major William E. Hoke, of Washington, D. C.

No. 2827: Casting in Long Life Molds.

The sand mold used in metal casting usually can be used but once and a new mold must be made for such casting.

In order to provide a mold that shall serve for repeated use and allow of rapid production a metal case which serves as a shield for the mold is used. In this especial device the shield is of iron and the invention consists in affixing to the iron a coating composed of finely divided clay mixed with a 10 per cent. solution of sodium. This is put on in successive coats, each of which is heated to about 350° F. The final coating is given a coat of lamp-black from an acetylene flame. This coat is renewed before each cast. The mold can be used repeatedly and with a revolving table and a number of molds as many as 14,000 small castings can be made per day.

This mold is in practical operation at the plant of the Holley Carburetor Company of Detroit, Mich.

In consideration of the novelty of the method of coating molds and the success of such coated molds, for the production of castings in a large commercial way, The Franklin Institute awards its Edward Longstreth Medal to Mr. Daniel H. Meloche, of Detroit, Mich.

No. 2831: Literature. The Louis Edward Levy Medal to Dr. Harvey C. Hayes, of Anacostia, D. C., for his paper on "Measuring Ocean Depths by Acoustical Methods," printed in the issue of the Franklin Institute's JOURNAL, for March, 1924.

No. 2832: The Franklin Medal to Prof. Pieter Zeeman, of Amsterdam, Holland, "in recognition of his numerous and important contributions in the field of magneto-optics and particularly of his discovery of the effect of a magnetic field upon the frequencies of the light from a radiating source."

No. 2833: The Franklin Medal to Dr. Elihu Thomson, of Lynn, Mass., "in recognition of his pioneer work in the field of electricity and electrical engineering and of his numerous inventions in these fields."

The Franklin Medals with accompanying certificates will be presented on the afternoon of Wednesday, May 20, 1925.

GEO. A. HOADLEY,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 11, 1925.)

RESIDENT MEMBERS.

CAPTAIN ROBERT W. A. BREWER, Consulting Engineer, 508 Atlantic Building, Philadelphia, Penna.

MR. R. L. GOETZENBERGER, Electrical Engineer, Frankford Arsenal, Philadelphia, Penna.

MR. C. N. JOHNSON, Electrical Engineer, in care of Westinghouse Electric and Manufacturing Company, 30th and Walnut Streets, Philadelphia, Penna.

MR. OSCAR STEINER, Mechanician, 131 North 19th Street, Philadelphia, Penna.

NON-RESIDENT MEMBERS.

REV. GEO. L. COYLE, S.J., Professor of Organic Chemistry, Georgetown University, Washington, D. C.

MR. FRANCIS F. LUCAS, Engineer, Bell Telephone Laboratories, Inc., 463 West Street, New York City, N. Y.

LT.-COL. FREDERICK POPE, Consulting Engineer, 60 Broadway, New York City, N. Y.

CHANGES OF ADDRESS.

MR. G. W. AKERLOW, 5342 Larchwood Avenue, Philadelphia, Penna.

MR. FRANKLIN BAKER, JR., The Park Lane, 48th and Park Avenue, New York City, N. Y.

MR. G. EDWARD BARNHART, 1547 East Walnut Avenue, Pasadena, Calif.

MR. CHRISTO CASACOF, 138 rue de la Tombe-Issoire, Paris, France.

PROF. CHAS. F. CHANDLER, 51 East 54th Street, New York City, N. Y.

MR. ARMIN ELMENDORF, 645 North Michigan Avenue, Chicago, Ill.

MR. J. LOGAN FITTS, in care of Warren Webster and Company, 17th and Federal Streets, Camden, N. J.

MR. WILLIAM A. HAINES, 238 Allen Lane, Mount Airy, Philadelphia, Penna.

MR. GEORGE R. HALL, 311 Finance Building, Philadelphia, Penna.

MR. J. K. M. HARRISON, Harrison and Company, Land Title Building, Philadelphia, Penna.

MR. J. MCGOWAN, JR., 2nd and Market Streets, Camden, N. J.

MR. F. M. MURPHY, 907 East 6th Street, Tucson, Arizona.

MR. JAMES STOKLEY, JR., in care of Science Service, B and 21st Streets, N. W., Washington, D. C.

COL. JOSEPH J. VOGDES, 310 Commercial Trust Building, Philadelphia, Penna.

MR. S. WEINBERG, 1913 Arch Street, Philadelphia, Penna.

MR. ALFRED L. W. WILLIAMS, 19 West 68th Street, New York City, N. Y.

NECROLOGY.

Mr. Sabin W. Colton, Jr., Bryn Mawr, Penna.

Mr. Henry S. Williams, 918 Chestnut Street, Philadelphia, Penna.

LIBRARY NOTES.

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BOOK REVIEWS.

COMBUSTION IN THE POWER PLANT: A COAL BURNER'S MANUAL. By Thomas A. Marsh, M.E. xi–251 pages, sixty-three illustrations, 12mo. New York, D. Van Nostrand Company, 1924. Price, $2.

In this compact, well-printed volume a large amount of valuable information concerning coal has been included. Although the main title would in strictness comprehend all forms of combustion, especially oil, the work is in great part limited to solid fuel. An excellent account is given of the composition of the coals from different parts of the world, obviously most in detail concerning the coals of the United States. These range from the Pennsylvania anthracite, practically unique, through the semi-bituminous and gas coals to the lignites of the west. Each type presents its problems of combustion. The means of securing the best results with each type are set forth in detail. A diagram shows the relative amounts of different types of fuel used in the United States, including for the purpose of comparison the energy developed by water-power. The diagram is in the usual form for such demonstrations, namely, a circle with radii. The coal consumption is practically three-fourths of the area. Oil takes up about half the last quarter and the remainder is covered by wood, water-power and natural gas. In the case of the "white coal," of course, the

proportion has to be expressed in energy produced, but with the others the quantity of material consumed is given. The data are subject to rather rapid change in proportion as the consumption of oil and the use of water-power are steadily increasing.

A serious problem with the softer coals is the smoke nuisance. While no special essay is devoted to this, the directions for operation of plants using coal are extensive and in much detail, and the coal user will find all he needs to inform him of the present known means of reducing smoke escape. Fuel oil and powdered fuel are given consideration. Comparisons are made of the efficiency and convenience of powdered fuel and coal in ordinary form fed by stokers. In the use of stokers trouble often arises in consequence of the change in the nature of the coal, but with pulverized fuel the simple adjustment of a valve accommodates the operation. Pulverized fuel requires proportionately less labor than with ordinary coal. Nothing seems to be said about the danger of spontaneous combustion in powdered fuel. This danger is, of course, very slight when the powdering is done at the plant at which the fuel is consumed and no large storage of the prepared material is made. The author deprecates giving overwhelming attention to the B.T.U. of the coal. The question of the value of a given sample is determined by many circumstances, each of which is considered in some detail. The work will be of great use to the engineer in charge of coal-consuming plants.

HENRY LEFFMANN.

FACTORY PRACTICE IN MANUFACTURE OF AZO-DYES. By W. B. O'Brien, Ph.B. 176 pages, illustrated, 8vo. Easton, Pa., The Chemical Publishing Company, 1924. Price, $5.

The author of this book is connected with the Flash Chemical Company, and presents a practical treatise upon an important specialty in synthetic dye manufacture. It is another one of the now encouragingly numerous instances of the development of the tar-products industries in the United States. There is still considerable indifference among people at large in this country concerning the importance of such an establishment of these industries as will render us fairly independent of the Germans. The development of the German color industry was the most striking instance history affords of the value of the equal cultivation of theory and practice. The book in hand gives a large amount of information in both fields. The composition of each color is shown by structural formulas and it is gratifying to note that these are correctly written. Some American chemists have the habit of attaching hydrogen symbols to each corner of the hexagon, but this really indicates an additive compound. Kékulé proposed the plain hexagon as the symbol for the entire benzene molecule.

The azo-dyes have long been known and have found wide applications. The Sudans have had the special value of solubility in oil and not in water, in consequence of which they have been used in staining tissue sections as a test for fatty matters and also largely as butter colors. The high coloring power of some of the more complex azo-dyes has been utilized in analysis. The fact, for instance, that the preliminary diazotization which is necessary for the production of the colors is effected with a nitrite, by Griess' reaction, has been applied in the detection of nitrites in water, giving the chemist one of the most delicate tests known.

Some statistics given in the introduction are interesting. Eighteen classes of dyes, including 240 different ones, were made in the United States in 1920, 148 of which were azo-compounds, that is, nearly two-thirds. As might be expected, the composition of the dyes ranges from the comparatively simple Sudans to much more complex associations. Thanks to the advance in the theoretical chemistry of the subject, the processes of transformation and the structural formulas of the finished products are well established. The procedures for each color are given in detail, all precautions necessary being set forth. The dyes considered are principally those of the monazo class. Factory practice is notably different from laboratory work. The large amount of materials that must be used to secure economic production constitutes a serious problem, and the short working day, now in vogue in the labor field, is also an interference which is not felt in the research laboratory. The author states that the advantage possessed by other nations due to their earlier development of the color industry has been materially offset by economic and circumstantial factors affecting the American industry. This is gratifying news.

In 1920 there was a total home production of over eighty-eight million pounds of dyes, valued at over ninety-five millions of dollars. In the same year less than three and a half million pounds of dyes were imported, of which Germany furnished little over half. About eighteen million pounds of synthetic indigo were made at a value of a little less than a dollar per pound.

The book contains no index, which is a serious omission. It is to be regretted that the term "nitrite of soda" is used in preference to the correct "sodium nitrite," and it is a little astonishing that this discredited phraseology should have passed the proof-readers of the Easton publishing house, which has been so long identified with high-class chemical literature. It is also a matter of some animadversion that while diazo and most similar prefixes are written as here given, "monazo" is written usually "mono azo," an awkward form for which there is no justification and no necessity. There are errors in grammar, especially the use of plural nouns with verbs in the singular, such as "two thousand pounds of water is run into the tub." This bad form occurs frequently. There is no justification for it.

For the chemist in charge of manufacture of these dyes and for the research worker who wishes to advance our knowledge in this interesting and important field, the book will be very welcome.

HENRY LEFFMANN.

THE ELEMENTS OF COLLOIDAL CHEMISTRY. By Herbert Freundlich. Translated by George Barger, F.R.S. vii–210 pages with diagrams, small 8vo. New York, E. P. Dutton and Company. Price, $3.

Of the making of books on colloid chemistry there seems to be no end. The vast expansion of the field within recent years is one of the most striking features of chemical literature. Graham would be interested to see how his initiative researches have expanded. Yet a note of retreat seems also to be feebly sounded. Graham's classification—inferentially, at least—of substances into colloid and crystalloid soon became inapplicable. It is, indeed, a sort of irony of fate that the particular substance from which the word "crystalloid" is derived, the quartz crystal, should be capable under very simple manipulation of assuming a true colloidal state. Early in the development of this phase of

chemistry the crystalloid and colloid "states" or "conditions" were recognized to be proper distinctions. The late Jaques Loeb, however, has disapproved even this method of distinction. In his recent book on proteins, he asserts that the utmost distinction that we can make is between "crystalloid and colloid behavior." The same set of molecules may be acting in one way as crystalloid and in another way as colloid. Complex proteins contain amino-acid residues, and these are crystalloid. Gelatin, he says, has two types of association in its molecule. One type is hydrophilic, that is, miscible directly with water, the other—which might be oleophilic—is easily associated with oil. Loeb has also pointed out that the formation of colloid complexes is not, as generally supposed, out of the regular stoichiometric laws, but obedient to them. The errors in this respect have been due to ignoring the hydrogen-ion concentration of the liquid. When this is determined and applied, it is found that there is strictly speaking no "colloid chemistry" as distinct from general chemistry, at least so far as proteins are concerned.

The author of the book in hand is connected with the Kaiser Wilhelm Institute of Physical Chemistry and Electrochemistry and is an honorary professor in the University of Berlin. The translator is professor of medical chemistry in the University of Edinburgh. We are assured, therefore, of an accurate text and an accurate translation. The text covers the usual material of elementary works on the subject. It seems to the reviewer that works of this class should devote much more space to illustrative experiments than is customary in them. There are very many simple illustrations available. References are made in all the works to the ultra-microscope, but more detailed information as to its construction and application might be given. There is now on the American market a form of dark-field illumination for use with the ordinary table miscroscope which has satisfactory application as an ultra-microscope, especially in pathology. Some description of this form might with advantage be given in elementary works.

The book in hand is comprehensive and well written and will undoubtedly take rank with the best treatises on the subject. Most of the illustrations are the familiar graphs, but a few outline drawings of apparatus are given. About half the text is devoted to capillary chemistry; the remainder to colloid disperse systems. The original treatise by Freundlich on "Kapillarchemie" involved considerable mathematical discussion. He prepared, however, at the suggestion of some associates, a work entitled "Grundzüge der Kolloidlehre," in which the mathematical deductions and numerical data were in great part elided, and it is this work that has been translated. It deals with the fundamental principles of the physico-chemical foundations of colloid chemistry and contains many technologic and biologic examples, making it especially applicable to students of medicine and bio-chemistry. Doctor Barger has rendered the German original into clear and correct English.

HENRY LEFFMANN.

POPULAR SCIENCE TALKS. 239 pages, 12mo, paper bound. The Philadelphia College of Pharmacy and Science. Price, $1.

This is the second volume of the publication of the popular lectures given at the Philadelphia College of Pharmacy and Science by the members of the instructional corps. The subjects include a wide range of information expressed

in language easily understood by the public at large. The lectures were largely illustrated and a fair proportion of these illustrations are reproduced in the volume. Some lectures relate to pure science, and others to everyday affairs, such as household chemistry and household pests.

KELVIN CENTENARY. Oration and Addresses Commemorative. 100 pages, 8vo. London, Percy Lund Humphries and Company, Ltd., 1924. Price, 6 s. net.

William Thomson, Lord Kelvin, was born on June 26, 1824. The centenary of his birth was celebrated under the auspices of the Royal Society, with the association of a committee containing members of the several Institutions of Civil, Mechanical and Electrical Engineers, the Physical Society and other technical bodies not specifically mentioned. The celebration was held in London on July 10 and 11, 1924. Sir J. J. Thomson delivered a memorial oration. Delegates were present from learned societies in different parts of the world and congratulatory addresses were also received from many sources. The volume contains the text of the Thomson address and the speeches at the memorial banquet. Sir J. J. Thomson's address was an interesting and valuable review of Kelvin's life and work.

PUBLICATIONS RECEIVED.

Crystals and the Fine-structure of Matter, by Friedrich Rinne. Translated by Walter S. Stiles. 195 pages, illustrations, portrait, 8vo. New York, E. P. Dutton and Company, 1924. Price, $4.20.

The Elements of Colloidal Chemistry, by Herbert Freundlich. Translated by George Barger. 210 pages, illustrations, 12mo. New York, E. P. Dutton and Company, 1924. Price, $3.

The Origin of Continents and Oceans, by Alfred Wegener. Translated from the third German edition by J. G. A. Skerl, with an introduction by John W. Evans. 212 pages, illustrations, 8vo. New York, E. P. Dutton and Company, 1924. Price, $4.50.

Theoretical and Applied Electrochemistry, by Maurice DeKay Thompson. 551 pages, illustrations, 8vo. New York, The Macmillan Company, 1925.

Profitable Science in Industry, by Dwight T. Farnham, James A. Hall, R. W. King, and H. E. Howe. 291 pages, illustrations, 12mo. New York, The Macmillan Company, 1925. Price, $3.50.

Subject List of the Periodical Publications in the Patent Office Library. Patent Office Library Series, No. 8. 282 pages, 16mo. London, His Majesty's Stationery Office, 1924. Price, two shillings.

Die Methoden der Theoretischen Physik, von Felix Auerbach. 436 pages, illustrations, 8vo. Leipzig, Akademische Verlagsgesellschaft, 1925. Price, in paper, $3.15; bound, $3.60.

Grundbegriffe der Mechanischen Technologie der Metalle, von Dr. Ing. Georg Sachs. 319 pages, illustrations, 8vo. Leipzig, Akademische Verlagsgesellschaft, 1925. Price, in paper, $3.15; bound, $3.60.

Nouvelles Vues Faraday-Maxwelliennes (supplément). Sur la Propagation de la Lumière, par Charles L. R. E. Menges. 44 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1924. Price, five francs.

Space and Time. An experimental physicist's conception of these ideas and their alteration, by Carl Benedicks with an introduction by Sir Oliver Lodge. 98 pages, 12mo. New York, E. P. Dutton and Company, 1925. Price, $2.

Helmholtz's Treatise on Physiological Optics. Translated from the third German edition. Edited by James P. C. Southall. Vol. ii, The Sensations of Vision. 480 pages, illustrations, plates, quarto. Ithaca, N. Y., Prof. F. K. Richtmyer, Secretary, Optical Society, Cornell University. Price, $7.

Les Notions Fondamentales d'Éléments chimique et d'Atome, par Georges Urbain. 171 pages, illustrations, table, 12mo. Paris, Gauthier-Villars et Cie., 1925.

National Advisory Committee for Aeronautics: Technical Notes, No. 212, Simplified Propeller Design for Low-powered Airplanes, by Fred E. Weick. 10 pages, plates, quarto. No. 213, Discharge Characteristics of a High-speed Fuel Injection Engine, by Robertson Matthews. 21 pages, plates, quarto. Washington, Committee, 1925.

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